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# Art Informing Science Education: The Potential Contributions of Ornithological Illustration to Ecology Education

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ART INFORMING SCIENCE EDUCATION:  
THE POTENTIAL CONTRIBUTIONS OF ORNITHOLOGICAL ILLUSTRATION  
TO ECOLOGY EDUCATION

A Dissertation  
Submitted to the Graduate Faculty of  
The Louisiana State University and  
Agricultural and Mechanical College  
In Partial Fulfillment of the  
Requirements for the Degree of  
Doctor of Philosophy

In

The Department of Curriculum and Instruction

By  
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B.S. University of South Florida, 1989  
M.N.S. Louisiana State University, 2002  
August, 2006

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This dissertation is dedicated to all past, present, and future naturalists, and to my nature-loving family in the United Kingdom.

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## ABSTRACT

Birds serve as an excellent group of organisms from which to introduce the study of ecology, being of inherent aesthetic interest to many otherwise uninterested in science, and are also ubiquitous in the immediate environment of many students. By extension, images of birds might serve as a valuable resource for the ecology educator, and bird artists – as a subset of ecologists - might provide useful models for expertise in ecology.

This study examines the potential contributions of bird artists and bird art to education in ecology at the high school and college level. Eight contemporary bird artists were interviewed in depth to provide a multiple case study for the development of expertise in field ornithology as a subspecialty of ecology. Forty narrative bird paintings and forty sets of plates from popular field guides to birds were analyzed for their potential classroom use. Twenty-five ecological concepts were identified within the sample of bird art examined, all of which are recommended for inclusion in the ecology curriculum. Additionally, images of birds were found to have considerable potential for illustrating and teaching the history and nature of science.

## CHAPTER 1: INTRODUCTION

### Rationale

“I hope you love birds, too. It is economical. It saves going to heaven”  
(Emily Dickinson, 1876).

Birds may truly be said to be the only other two-legged organisms on earth that have intrigued man since the Stone Age (Kastner, 1988). Among other factors, the fascination of birds for man stems from their availability to the casual observer, the sensory appeal of their bright coloration and the texture of feathers, and an almost mystical identification with the ideal of personal freedom represented by the power of flight. In addition, the image of birds appears to provoke an acute identification with the natural world in many individuals (Kastner, 1988). Edwin Stresemann (1975) speculates that long before ornithology became a methodological science in the late 18<sup>th</sup> and early 19<sup>th</sup> centuries and birding became an extensive and commercially important leisure interest in western culture in the 20<sup>th</sup> century, there has always existed a substantial proportion of human beings for whom birds satisfied some instinctive desires. Hunting, trapping, observing, and admiring birds satisfied such vague longings, and these activities frequently evolved into a focused passion, producing new scientific knowledge and deeper understanding of the organisms and their environment.

The making of images of birds has a long and venerable history. The artistic expression of interest in birds is evident today in the many ornithological illustrations currently found in field guides, art books, gallery paintings, museum catalogs and in technical articles and textbooks. As an interest in birds has manifested across many cultures and walks of life, bird art also has a wide appeal and occupies niches within art, science, and history. For example, the oldest known depictions of birds on cave walls in southern France and northern Spain (c. 14,000 B.C.) frequently show the ravens that accompanied the conclusion of a successful hunt, and bird

illustrations in the psalters of the Middle Ages emphasize the symbolic and spiritual importance of these organisms. As interest in science reawakened in the Renaissance, Leonardo da Vinci executed detailed studies of bird anatomy intended ultimately to open the power of flight to humans. Five centuries later, following the establishment of ecology as a sub-discipline of biology and the public concern with the environment that followed, birds appeared as a conservation motif in the works of twentieth century landscape painters such as Lars Jonsson and Bruno Liljefors. Both the intrinsic appeal of the subject matter and the wide availability of bird art suggest that there is much potential for educational use of these images.

Ornithologist Frank Gill (1995), wildlife ecologist Stanley Temple (1977), and population biologist Paul Ehrlich (1970; 1988) are among many authors who have pointed out that avian biology and ecology have wide implications in biology, at the level of the individual, the population, the community, and the ecosystem. Many bird illustrations explicitly or implicitly convey aspects of bird biology that demonstrate, explain, or reinforce wider concepts in ecology. Straightforward bird portraits, such as those found in field guides, introduce such as ideas as adaptation, as they distinguish between bill, wing, and foot structures of different taxa, and also visual communication, evolution of displays, and sexual selection, as difference in plumages between genders and in different seasons are illustrated. Narrative paintings that show mixed species of birds- and also include other organisms- introduce aspects of community biology, the interdependence of species, food webs and energy flow, and may portray important and relevant aspects of the local habitat or wider region where the organisms are typically encountered. Such morphological, behavioral, and environmental concepts are integrated into many college textbooks in the areas of ecology and evolution (e.g., Campbell and Reece, 2002; Starr, 2005; Starr and Taggart, 2004). Additionally the, *National Science Education Standards*

(NRC, 1996) recommend that characteristics of organisms, their life-cycles, behavior, their relationships to the environment, diversity and adaptation, interdependencies between species, and studies of populations, communities, and ecosystems be addressed at the grade school level, especially as these relate to the theory of evolution, which now occupies a central position in biology and biology teaching. Many of these topics have the potential to be introduced or demonstrated by carefully selected ornithological illustrations, and a particular advantage of so doing is that of all the vertebrates, live birds are a visible and ubiquitous presence throughout the day for most students, and thus reinforcement of these concepts and principles is close at hand.

The lives of those who paint birds professionally may also have much to teach those concerned with a transformative approach to curriculum. No formal training program exists for this specialized field of endeavor, which requires a degree of considerable expertise in both science and the visual arts, and the majority of bird artists have been forced to craft their own education from a variety of formal and informal sources. Professional success in this field frequently not only has provided material results in a life of travel, discovery, and productivity, but also has conferred an enviable degree of personal fulfillment upon the artist-naturalist. The biographies and life-stories of bird artists thus may model for the educator how a carefully nurtured passion may develop into a specialized expertise with the power to enlighten and transform lives.

### Goal of the Study

The goals of this study were twofold: to construct a picture of the life pathways and practices characteristic of selected contemporary bird artists, and also to examine narrative and technical bird images in terms of their potential for science learning. Extensive interviews of eight bird artists of different interests and backgrounds were conducted. Artwork was selected from on-

line archives of narrative paintings and portions of popular field guides in order to describe the particular types of ornithological and ecological knowledge that may be conferred upon the viewer via such images, and to suggest where and how ornithological illustration might be useful to the biology educator.

### Research Questions

The primary research question that guided this study was: What implications do the life histories, practices, and products of eight selected ornithological artists have for education within the area of ecology at the high school and college level?

The specific sub-questions within this general line of inquiry were:

1. What commonalities are revealed by the life-stories of contemporary ornithological artists? In particular, what are the conditions and factors associated with the development of expertise in both the visual arts and ornithology?
2. Is there evidence of a ‘naturalist intelligence’ as described by Gardner (1999) or a naturalist worldview as described by Janovy (1986/1996) in the life-stories of these artists? If so, how and when does this disposition manifest, and what conditions and factors are associated with its optimal development?
3. Are the products of these and other ornithological artists consistent with Edward Tufte’s (1983; 1990; 1997) principles of graphical design, with respect to the transmission of qualitative, quantitative, and relational informational, and the stimulation of reasoning processes in the viewer?
4. How might ornithological imagery be used effectively in the high school and college classroom?

### Gowin's Vee Diagram of Research

The Gowin's Vee (Gowin, 1981) is a heuristic that attempts to penetrate the structure and meaning of knowledge, and was utilized here to guide the processes of this study (Figure 1.1). The center of the Vee stated the research question and sub-questions. The events and objects used in the construction of answers were listed at the point of the Vee. The right side of the Vee showed how knowledge and value claims were derived from data (records) and data transformations. The left side of the Vee outlined theoretical aspects of the study, indicating the relevant concepts, principles, and theories utilized, and also stated the worldview driving the research.

The initial data set that was analyzed for answers to the sub-questions consisted of transcripts of interviews with eight contemporary bird artists, selected for their eminence in the world of ornithological illustration. The data set also included the products of ornithological illustrators and included 40 narrative paintings obtained from on-line archives of bird art, and 40 plates obtained from four popular and respected field guides to birds. The particular field guides selected were *Eastern Birds* (Coe, 2001), *Birds of North America* (National Geographic Society, 2002), *Eastern Birds* (Peterson, 1980), and *The Sibley Guide to Birds* (Sibley, 2001). Because the questions were somewhat emergent in nature, additional sources of data such as biographies of other bird artists, reviews of bird paintings and field guides, and additional images were included in the study where initial results indicated that these were appropriate.

### Flow Chart Representation of Research Process

An overview of this research is shown in a flow chart diagram (Figure 1.2). The first phase of the research was to search and summarize the literature upon explicit and implicit

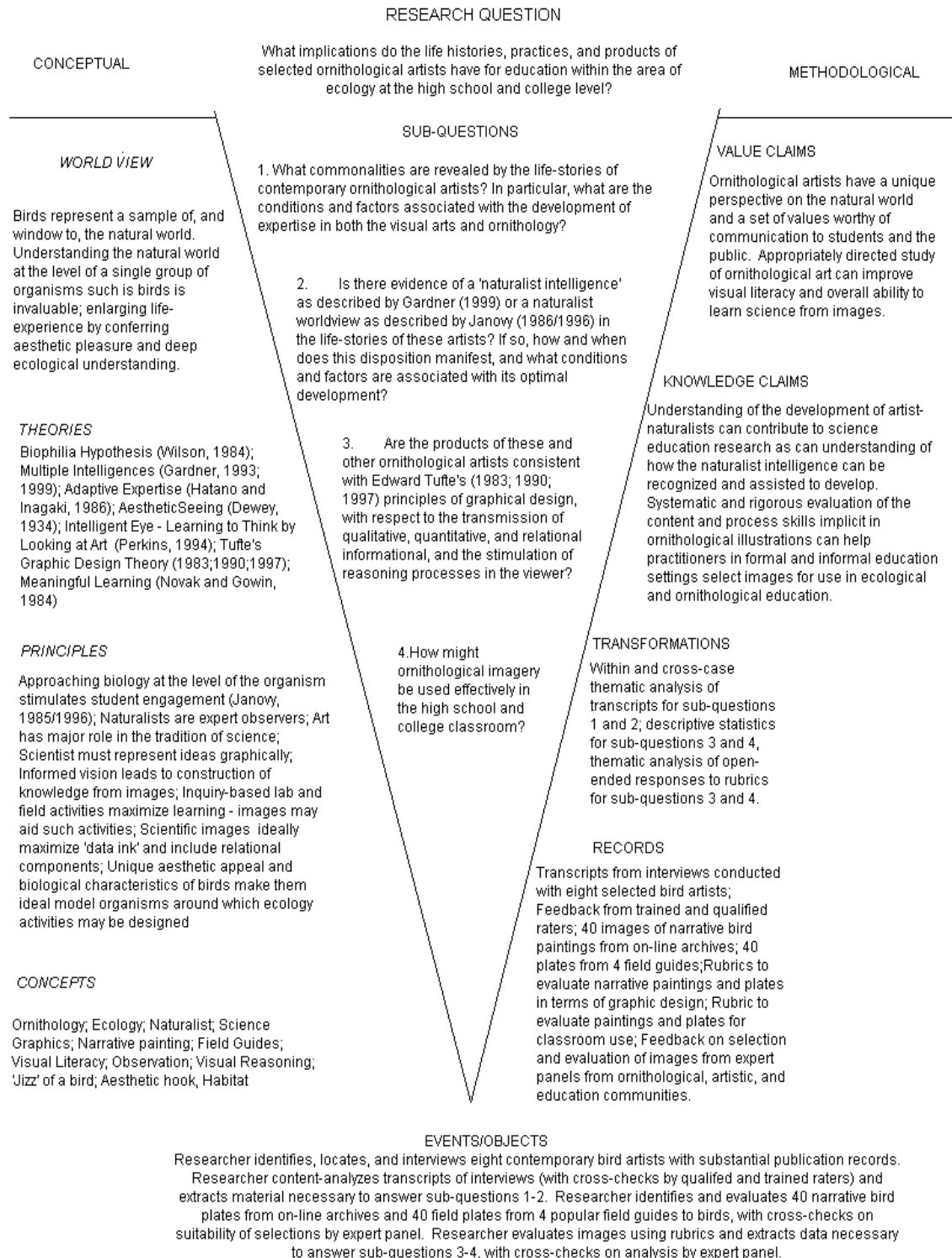


Figure 1.1 Gowin's Vee Diagram of Research



concepts related to the topics under investigation, including a survey of ornithological illustration, biographies of bird artists and naturalists, multiple intelligence theory, the biophilia hypothesis, graphic design theory, aspects of visual learning and visual literacy, and the use of images in science education. Following the literature review, the active aspects of the study are divided in three related strands of inquiry.

The first strand of the research aimed to answer the first two sub-questions, which address the lives, practices, and dispositions of selected ornithological illustrators. Eight bird artists were interviewed, and the resulting transcripts coded and partially analyzed. The next phase of this part of the study submitted the coding regimen and analysis for review by qualified independent coders for feedback, after which appropriate revisions were made.

The second and third strands of the project addressed the quality of bird art with respect to transmission of scientific information and ideas, and the potential uses of such images in teaching ecology.. A sample of narrative paintings and field guide plates were selected, and after review for suitability by an expert panel, each was evaluated by two rubrics. One rubric assessed the degree of adherence to a set of criteria for scientific graphics developed by Edward Tufte (1983; 1990; 1997), while the second – in the third strand of the research – assessed how each painting may be used in the biology classroom. Both the quality of the rubrics and my evaluations of the images were reviewed by expert panels composed of individuals familiar with the field of bird art (for the second strand of the research; sub-question three) and experienced science educators (for the third strand of the research; sub-question four). When a high level of agreement (~80% or more) was reached between my selections and assessments and the opinions of the panels, results were compiled and summarized. Finally, a summary of both

evaluative studies, and the final analyses of the interview transcripts was presented with the dissertation.

### Significance of the Study

This study is guided and driven by the following major ideas: that the study of whole organisms in their natural environment not only contributes to biology as a discipline but confers considerable benefits to the ‘student’; that images are critically important to the learning of science; and that the life-stories of those who follow a profession combining art and science have great potential value to the biology educator.

We perceive the living world as a set of organisms. While biology is rich in theory and abstraction, it is fascination with plants and animals that has historically exerted the greatest influence upon biological thinking, and that has fundamentally driven the science. As Janovy (1985/1996) asserts that, “while we endure abstractions, we prefer to see things that are alive. Failing that, we like to see things that our minds can easily translate into living organism. More often than not, this desire is manifested as dependence on a picture” (p. 35). It is generally understood that science learning is dependent upon art as a form of communication. The majority of student encounters with scientific images occur via the medium of prescribed texts, textbooks at all grade levels are becoming more pictorial, and illustrations are assuming a pivotal role in instruction (Blystone and Dettling, 1990). Outside the classroom, images reduce the complexity of nature to the comprehensible for the public, and serve as a source of collective awareness for those unable to experience certain locales and phenomena directly. In terms of environmental education, the emotional and aesthetic hook provided by an image effectively communicates the ecological consciousness of the biologically oriented to those who might

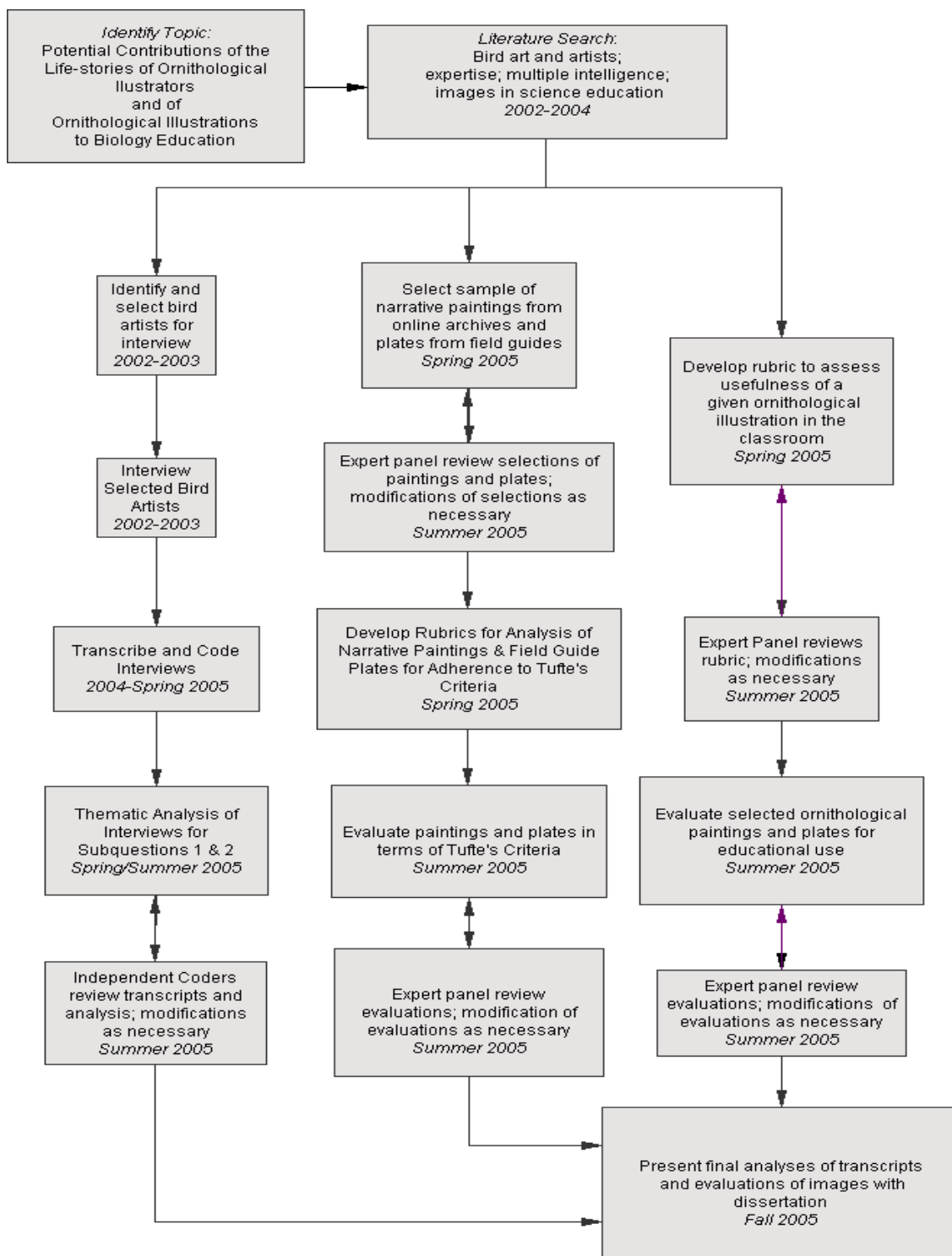


Figure 1.2 Flow Chart Depicting Major Benchmarks of Study

otherwise be inclined to discard 'environmentalism' as being antithetical to their way of life (Janovy, 1985/1996). Images of organisms may also contribute to an implicit understanding of the nature of science, serving as a "window ... into the workings of a scientist's mind (p.34) and teach "the scientist's approach to the new" (p.87).

Life-history writing offers a non-traditional perspective upon issues of schooling and education, particularly with respect to those that fall outside the realm of formal and institutionalized learning (Wolcott, 1994), and whereas the products of natural history illustrators serve important spiritual and utilitarian functions in formal and informal biology education, study of the artists who produce the images also has significance for the field. Those biologists who spend their professional lives producing visual descriptions and explanations of a group of organisms - to which they have frequently devoted decades in observation, study, and reflection - are exemplary teachers and learners in the broadest sense. Such individuals have escaped powerful pressures to conform to the demands of more conventional occupations within the discipline, have been driven and fueled by a pure form of scientific curiosity, have maintained a distinctly individual value system, have developed their potential in a manner that results in unique contributions to science, and by their disciplined self-awareness demonstrate moral consciousness and social responsibility (Janovy, 1985/96; Montagu and Matson, 1983). It is difficult to imagine a more positive outcome for science students, and since one aim of qualitative research is to affect and improve educational practice, an inductive analysis of the development of such lives may have much to offer the thoughtful educator. Allowing for the limited generalizability of the study (Gall et al., 1996) and that the meaning and knowledge constructed will necessarily reflect the values and worldview of the naturalist tradition within

biology, this analysis of the way in which these artist-naturalists have constructed their professional lives may contribute to increased awareness of issues, influences, and choices that are relevant to our students. This dissertation aims to open a new window of instruction and understanding that can be used by the biology teacher and the biology educator, and has the potential to teach basic ecology more effectively via images of birds.

#### Definition of Selected Terms Used Throughout Manuscript

Adaptive Expertise – describes the ability of certain ‘virtuoso’ experts to progress rapidly when undertaking study of a new domain, or an area within their domain that is outside their specialty, for they are able to approach new material as expert thinkers and learners.

Adaptive experts are characterized by a capacity for metacognition.

Aesthetic Seeing - intense mode of perception conceptualized by John Dewey (1934). Rooted in the discernment of fine distinctions, aesthetic seeing allows the observer to go beyond identification and recognition towards an educated empathy that allows the gestalt of the observed to emerge.

Aesthetic Hook – when an image serves to engage the viewer with content by means of an attractive or compelling design.

Aldrovandi, Ulisse – 16<sup>th</sup> century naturalist and professor at the University of Bologna, author of a multi-volume illustrated treatise on birds *Ornithologiae hoc est de avibus historiae*, considered to represent the zenith of ornithological knowledge and illustration in the Renaissance.

Aletheic gaze – an open, undemanding, and supple mode of vision, in which the subject does not employ a fixed perspective or ask defined questions of the object, but is instead willing to allow the gestalt to manifest.

Aristotle – authored the largest and most ambitious treatment of birds of any classical writer in book IX of the *Historia animalium* circa 350 B.C. After the collapse of the Roman Empire, the treatise was preserved by Arab scholars at Thessalonika, from where it appeared in translation in the Middle Ages and exerted a considerable influence upon European ideas of zoology.

Assertoric gaze – A searching and demanding mode of vision, ego-logical, inflexible, and exclusionary, and according to Heidegger, dismissive of any possibility of reciprocity between subject and object.

Belon, Pierre – Renaissance writer on natural history, interested in comparative anatomy and taxonomy, and author of *L’histoire de la nature des oiseaux, avec leurs descriptions & Naïfs portraits retirez du Naturel* (Paris;1555), the first book ever to commission ornithological drawings.

Benchmarks for Science Literacy – A vision of desirable science content and process competencies for all grade levels by the American Association of the Advancement of Science (1993).

Biogeochemical cycles - Movement of matter within or between ecosystems; caused by living organisms, geological forces, or chemical reactions. The cycling of nitrogen, carbon, sulfur, oxygen, phosphorus, and water are examples.

Biophilia Hypothesis - A somewhat controversial hypothesis put forward by Edward O. Wilson; the idea that humans evolved as creatures deeply enmeshed with the intricacies of nature, and that we still have this affinity with nature ingrained in our genotype.

Carrying Capacity – the maximum population size of a given species that a given environment can support with the resources available.

Chartjunk - elements of an image that do not convey information and serve to distract attention from the real content of the image (Tufte, 1983)

Cognitive scaffolding (also instructional scaffolding) – presenting students with a framework that helps to organize meaningful and productive thinking.

Concept – A verbal label designating a pattern in, or grouping of, objects or events.

Conditionalized knowledge – knowledge that is stored with a specification of the contexts in which it is likely to be useful; when, where, how, and why the knowledge is applicable. Conditionalized knowledge can be fluently and flexibly retrieved and is a characteristic of expertise.

Constructivist View of Education - the premises of constructivism as an epistemology are: that knowledge is constructed by the student rather than transmitted to the student, that prior knowledge impacts the learning process, that initial understanding is local rather than global, and that building useful knowledge structures results from purposeful activity and effort.

Creative tension - conditions that combine to stimulate optimum performance, conceived of as incorporating sources of both stability and confidence, autonomy without isolation, and time available for independent work that does not exclude stimulating interactions with colleagues.

Creativity – the demonstrated ability to generate ideas or products that advance a domain, or deepen understanding within a domain.

Cryptic coloration – also known as concealing coloration, cryptic coloration describes coloration

that allows an organism to match its background and hence become less vulnerable to predation or recognition by prey.

Data-Ink – the proportion of ink (or paint) within a graphic that is used to convey information, and does not have a solely decorative or structural purpose (Tufte, 1983)

Deductive Method – systematic connection of causes and events, as in the scientific method.

Democritus – Greek mathematician and philosopher (circa 450 BC) known for expanding the atomic theory.

Derrida – 20<sup>th</sup> century Algerian-born French philosopher closely identified with the methodology of deconstructionism, a theory of reading that aims to undermine the logic of opposition within texts.

Descartes – Influential western philosopher (17<sup>th</sup> century) with a strong interest in mathematics and physics. Descartes rejected religious authority in the quest for scientific and philosophical knowledge, emphasized the importance of methodology, and in the pursuit of absolute certainty, attempted to raise philosophical argument to an exact science.

Dewey – 19<sup>th</sup>/20<sup>th</sup> century American educator, psychologist, and philosopher, known for his championship of pragmatism. In *Art and Experience* (1934), Dewey argues that aesthetic experience is a route to expanding meaning within an individual's life.

Disinformation in illustration – concealment of relevant details, or due to the introduction of noise that diverts the eye from content, such as the activation of negative space by frames or irrelevant background.

Diversity- the number and relative abundance of species within a given environment

Ecology – Study of the interactions between organisms and their environment, including interactions between and within species.



Ecomorphological relationships – the relationships between structure of organisms and features of the environment (including dietary relationships).

Ecosystem - An ecosystem consists of a dynamic set of living organisms (plants, animals and microorganisms) all interacting among themselves and with the environment in which they live (soil, climate, water and light). Contrast with 'habitat' and 'niche'. An ecosystem does not have precise boundaries - it can be as small as a pond or a dead tree, or as large as the Earth itself. An ecosystem can also be defined in terms of its vegetation, animal species or type of relief, for example. The major ecosystems are generally described as: aquatic ecosystems (saltwater or freshwater ecosystems) or terrestrial ecosystems ( forests, prairies, deserts, etc).

*Eidos* – A Greek term for what is seen—figure, shape, or form. In Greek philosophy, the *eidos* refers to the gestalt of what is seen, or the immutable genuine nature of an object as apprehended by human reason.. Husserl used the term "eidetic" for the phenomenological apprehension of essences.

Electrophoresis - A method of separating large molecules (such as DNA fragments or proteins) from a mixture of similar molecules. An electric current is passed through a medium containing the mixture, and each kind of molecule travels through the medium at a different rate, depending on its electrical charge and size. Separation is based on these differences.

Energy Cycling – the movement of nutrients through an ecosystems, involving and dependent upon photosynthesis, respiration, biosynthesis, biomass, net primary production, and decomposition.

Environmental Science – an interdisciplinary area concerned with the interactions between the physical, chemical, and biological components of the natural world, including specific areas of study such as ecology, environmental engineering, and conservation biology.

Epistemological vision - a local perception, analytical, realistic, and non-mystical., a mode of vision that seeks to gather (rather specific) knowledge.

*Essent* – a term coined by Martin Heidegger to mean “being”; specifically the presencing of the Gestalt.

Evolution – the modification of organisms over time, as a result of changes in the frequency of alleles, or mutation.

Evolutionary theory – a body of knowledge attempting to describe and explain changes in organisms over time, incorporating mutation, population genetics and variability within a population, and the mechanisms of natural selection.

Expertise – highly developed procedural and declarative knowledge about a particular domain that can be applied effectively in unfamiliar and ill-structured situations.

Expert Knowledge Base - expertise about or within a domain that is subject to continual modification as the possessor reflects upon the solution of problems, and his or her own thinking, extracting generalizable knowledge from particular problems. Possession of an expert knowledge base also continually builds expertise.

Expert Ornithological Illustrator - for purposes of this study, an expert ornithological illustrator is an individual who has been a principal artistic contributor to a field guide or recognized technical publication.

Expert Thinking and Learning - is characterized by a high level of interaction between the

general and particular, frequently using the particular to enhance knowledge and understanding of the general. In contrast, non-expert behavior is characterized by a unidirectional flow of information and skills. Thus expert problem solving is characterized by knowledge transformation, rather than the knowledge-telling approach common to novices.

Factor – Choice Approach – One theory of vocational choice developed by Holland (1966) in which career choice is driven by personality (categorized by a preference for realistic, intellectual, social, conventional, scientific, or artistic activity) in conjunction with environmental factors.

Family – A taxonomic group containing one or more genera, e.g., “The Eastern Phoebe is a member of the Empidonax Flycatcher family”

Figure/Ground – the visual system tends to oversimplify a visual phenomenon into a figure to which most attention is paid, and a ground which contains everything else and functions as background.

Fitness – Biological ‘fitness’ is measured by the number of offspring produced by an organism that survive to reproductive age.

Fluid Mosaic Model – a model of bi-layer lipid membranes, a two dimensional fluid in which membrane lipids and proteins are constrained within the plane of the membrane in which they are embedded, but are free to diffuse laterally.

Food Webs – an often-complex system of relationships between plants, animals, and energy, based upon nutrient and energy flow from the source of light energy through plant producers to consumers of various types. Nutrient flow is not a strictly linear process as

implied by the misused term ‘food chains’, although small food chains do exist within complex food webs.

Forward/Backward Reasoning – Forward reasoning (characteristic of experts) involves a top-down or funneling approach to problems, in which laws, principles, and concepts are referred to first. In contrast, backward reasoning, or the hypothetico-deductive approach to problem solving, is characteristic of a novice and employs a bottom-up or shotgun approach, using details, facts, and operations utilizing these. Thus forward reasoning works from the given information to the unknown and is knowledge-based; backward reasoning works from a hypothesis about the unknown back to the given information and is goal based.

Foucault – French philosopher and social critic of the 20<sup>th</sup> century variously identified as a postmodernist, a structuralist, and a post-structuralist. Foucault is best known for critiques of various social institutions, particularly psychiatry, medicine, and the prison system, and also for his works on the history of sexuality and the relationship between power and knowledge.

Frederick II - of Hohenstaufen, Holy Roman Emperor, King of Sicily and Jerusalem, 13<sup>th</sup> century. His book, *De Arte Venandi cum Avibus* (On the art of hunting with birds) was the first attempt to document the natural history of birds based upon personal observation, free of legend and dogma and also refuted inaccuracies in *Historia animalium*.

Frequency of occurrence – in bird books, the likelihood of observing a given species in a particular area is indicated by terms such as “common”, “rare”, “winter visitor” etc.

Frontal ontology – the viewing of an object with a rigid and predetermined quest for

understanding, i.e. with epistemological vision or Heidegger's assertoric gaze.

*Gelassenheit* – literally meaning 'quiet manner' in German; the term used by Heidegger to describe an ideal visual approach, in which the subject's approach to the object is ontological, employing the aletheic gaze and allowing vision to become a route to transformative knowledge.

Genre – A generally recognized category or style in art

Genus - A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species.

Gesner, Konrad von – 16<sup>th</sup> century Zurich physician who authored the first popular illustrated book about birds *Qui est de avium natura* (Zurich, 1555); one that was reissued for two centuries.

Graphical Integrity – exists when an artist or designer explores the subject matter to the greatest extent possible, avoids deceiving the viewer by depicting data out of context, allowing parts of the graphic to generate expectations about other parts and by visual drifts in scale (Tufte, 1983).

Habitat - the location in which a species lives... contrast with 'niche' and 'ecosystem'.

Hegel – 19th century German philosopher, who criticized the traditional epistemological distinction between subjective and objective in *Phenomenology of Mind* (1807)

Heidegger – 20<sup>th</sup> century German philosopher who applied the methods of phenomenology to ontology, in an effort to comprehend the meaning of "Being", both generally and in respect to its concrete appearance.

Heuristic – a device employed as an aid to solving a problem or understanding a procedure, such as the Gowin’s Vee or a concept map.

Ill-Structured/Well-Structured Problems – ill-structured problems resemble problems found in real life or professional practice. There is no obvious right answer, vaguely defined goals, and the information available to the problem-solver is incomplete and/or ambiguous. A well-structured problem implies a single correct answer, and a clear path to the solution, for it is obvious which concepts, principles, and rules should be applied.

Inconsequential species – species of no overt economic or aesthetic value.

Inquiry –based learning – where students construct much of their knowledge from posing and answering their own questions.

Interspecific competition – competition for resources between two or more different species.

Intra-specific competition – competition for resources between members of the same species.

‘Jizz’ - Birding slang for the gestalt or the essential character of the bird. In wide use among amateur bird-watchers and professional ornithologists alike.

Laws - A scientific law is a description of a natural phenomenon or principle that invariably holds true under specific conditions and will occur under certain defined circumstances.

Life-cycle (diagrams) – Diagrams indicating the different stages of an organism’s growth and development, possibly including all stages from fertilization of the zygote through reproduction as an adult to death.

Life-history Strategies – describes the ‘solution’ a given species is implementing with respect to the inevitable trade-offs between fecundity (clutch size in birds), annual survival rate (often negatively correlated with fecundity) and ecological factors.

“Little Brown Jobs” - or LBJ’s. Birder’s slang for small dull-colored species without

outstanding field marks, such as many wrens and thrushes, that are notoriously difficult to identify accurately at a distance.

Linnaeus – Carl Linne was a Swedish professor of medicine and natural history, known as the ‘Father of Taxonomy’ following publication of his rules for classifying organisms in *Systema natura* (1758).

Meaningful knowledge – content knowledge that is well organized and reflects appropriate contexts, such that content knowledge is chunked and reflects appropriate contexts important and relevant information can be rapidly retrieved.

Mentor – an individual significant in assisting an individual in the development of a talent or interest, or in facilitating educational and career path.

Merleau-Ponty – 20<sup>th</sup> century French philosopher whose work on perception was rooted in phenomenology. Merleau – Ponty adopted an ideal of vision dubbed ‘revelatory illumination’ by Martin Jay (1993), that resembles Dewey’s ‘aesthetic seeing’

Metacognition – reflecting upon one’s own thinking and understanding and probing the limits of one’s knowledge, such that one realizes when understanding is incomplete, when apparent discrepancies are actually the result of lack of knowledge or incomplete understanding, and retreating from initial interpretations of a phenomenon to search for deeper understanding of issues.

Monera – a taxonomic group that comprises the prokaryotes (bacteria and cyanobacteria).

Prokaryotes are single-celled organisms that lack a membrane-bound nucleus and usually lack membrane-bound organelles such as mitochondria and chloroplasts. They have a small ring of DNA as their genetic material and reproduce asexually. Contrast with the kingdoms of eukaryotic organisms (protists, plants, and animals).

Morphology – the configuration or structure of organisms

Morphometrics – quantitative aspects of the structure of organisms.

Mughal Court Painters – of 16<sup>th</sup> and 17<sup>th</sup> century India. The Mughal Emperors ordered paintings of birds and the production of illustrated books containing detailed pictures of birds, leaving a substantial legacy of bird art.

Multiple Intelligence - The theory of Howard Gardner that intelligence is not a generalized ability but takes the form of nine different potentials that become developed to the extent that an individual's environment permits. The intelligences listed by Gardner (1983;1999) are: verbal-linguistic intelligence, mathematical-logical intelligence, musical intelligence, visual-spatial intelligence, bodily-kinesthetic intelligence, interpersonal intelligence, intrapersonal intelligence, the naturalist intelligence, and existential intelligence.

*National Science Education Standards* – a document prepared by the National Research Council (1996), outlining a vision of science literacy and understanding desirable at all grade levels.

Natural History – The study and description of organisms and natural objects, especially their origins, evolution, and interrelationships.

Natural Science - A science, such as biology, chemistry, or physics, that deals with the objects, phenomena, or laws of nature and the physical world.

Natural Selection - an interaction between the phenotype of an organism and features of its environment that results in reproductive advantages for the organisms with the phenotype best adapted to that environment. Natural selection is the principal mechanism of evolutionary change.



Naturalist - an amateur or professional biologist interested in the study of whole organisms at a local level.

Naturalist Disposition – described by John Janovy (1985/1996) as an approach to life and work shaped by the study of organisms in their natural habitat and characterized by humility, flexibility, patience, resourcefulness, pragmatism, and a high tolerance for ambiguity.

Naturalist Intelligence – one of the forms of intelligence listed in Gardner's theory of Multiple Intelligence: An innate ability to perceive elements of the natural world keenly, to discriminate between organisms by identifying common features and unique characteristics.

Naturalist Worldview – characteristic of committed naturalists is an identity rooted in what is perceived as important in the natural world, and a purist tendency to center their world upon the chosen organism or group of organisms, without feeling the necessity to justify their passion in social or economic terms.

Nature of Science – includes the character and history of science, and the way science works.

The nature of science has three principal components: the scientific world view, scientific methods of inquiry, and the nature of the scientific enterprise.

Nietzsche – 19<sup>th</sup> century German philosopher who accorded an almost mystical value to observations made via prolonged contemplative engagement with the object(s) of vision.

Normal Science – science that progresses smoothly and cumulatively by incremental additions to existing knowledge. This view of science was challenged by American philosopher and historian Thomas Samuel Kuhn (1922-1996), who argued that the history of science reveals that scientific progress occurs through revolutionary change in paradigms of inquiry and explanation.

Ocularcentrism – an epistemology based upon visual or ocular metaphors.

Ontological vision - a more global mode of perception in which the viewing subject experiences the character or gestalt of the object.

Ornithology – the systematic scientific study of birds.

*Ousia* – an Aristotelian conception referring to the ultimate foundation of being or existence.

Narrative bird painting - bird paintings not primarily intended to illustrate technical points about the species. Narrative paintings tend to be decorative in function, but may contain great amounts of ornithological and ecological information.

Niche - a description of all the chemical, physical, and biological factors for a species' survival.

Paradigm – a prevailing pattern, model, or viewpoint within a domain such as science or art.

Parallelism – a design approach to the problem of highlighting relevant details that function in explanation, relying upon invoking comparisons by use of strategies of repetition and change within the image.

PGP (particular-general-particular) – a design solution to the problem of conveying complex information, where two particulars highlight and help to explain the general data arrangement (Tufte, 1997)

Phenomenology – a discipline of philosophy that is concerned with the study of consciousness, or structures of experience, from the first person point of view. Literally, phenomenology is the study of "phenomena": appearances of things, or things as they appear in experience, or the ways in which things are experienced, and the meanings things have in our experience.

Phylogenetic relationships – relationships between organisms that indicate a shared evolutionary history

Players – one category of scientist in a classification scheme conceived by McCain and Segal (1989). A ‘player’ represents a scientist motivated by the intrinsic pleasure of playing the game of science, particularly by curiosity, the stimulation of uncertainty, the aesthetic pleasure of making an original observation or creating a new idea, the contest with nature, and intellectual stimulation.

Pliny the Elder – also known as Gaius Plinius Secundus, a prosperous and educated Roman who authored the 37 volume *Natural History* (*Naturalis Historia*) in AD 77.

Population Biology – spatial and genetic aspects of a group of organisms of one species within a defined area.

Predictor Variable – an event or condition that is correlated with the subsequent events or conditions.

Principles – in science, principles are guidelines to theory and methodology that do not have the universal character or empirical basis of laws.

Protists - any of the eukaryotic, unicellular organisms of the former kingdom Protista, which includes protozoans, slime molds, and certain algae. The newest classification system recognizes eight ‘candidate kingdoms’ of these unicellular eukaryotes.

Rationalism – a philosophical movement, originating in the 17<sup>th</sup> century with Descartes, holding that all ideas are known through reason rather than experience.

Reductionism – a mode of thought, typical of scientific investigation, where problems are reduced to their smallest elements. In complex systems, reductionism may fail to consider important influences upon the larger problem.

Relational images - link two or more variables and encourage the viewer to assess possible causal relationships.

Romanticism – 18<sup>th</sup> century philosophical movement originating in Germany, which discarded rationalist ideas of innate norms of reason. Romanticism asserted man's essential unity with nature, held that intellectual and emotional capacities were innately integrated as was the conscious with the unconscious, that facts were value-laden, and sought to identify subject with object.

Sartre – 20<sup>th</sup> century French philosopher who claimed that "the gaze," the act of looking itself, was necessarily a hostile activity in which the subject looked at is inevitably reified or rendered an object that cannot provide a mutual reciprocity or dialogue with the viewer.

Schema – a model imposed on a complex phenomenon or experience by which an individual mediates perception, and constructs explanation. The schema has a key role in guiding response to complex phenomena and experiences. Organized conceptual schemas are important in expertise, for experts characteristically possess a formalized schema that guides how problems are represented and understood, and upon which the expert can draw and organize his or her thoughts around the big ideas that structure the schema. In contrast, novices are more concerned with identifying the operations by which they can manipulate facts and details to produce solutions.

Scientific Literacy - the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. It also includes specific types of abilities, such as being able to ask, find, or determine answers to questions derived from curiosity about everyday experiences, and to describe, explain, and predict natural phenomena. Scientific literacy implies that a person can evaluate the quality of scientific information on the basis of its source ,and the methods used to generate it. Scientific literacy also implies the capacity to

pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (NRC, 1996).

Scientific method – a deductive approach to scientific investigation involving empirical processes of discovery and demonstration. The scientific method begins with the observation of phenomena, the formulation of a falsifiable and testable hypotheses concerning the phenomena, an experiment to demonstrate the validity of the hypothesis, and a conclusion that validates or modifies the hypothesis.

Spectatorial epistemology (Spectator Theory of Knowledge) – a way of experiencing the world that is based upon the visual, in which the eye is the gateway between the objective and the subjective, where ‘the world’ and its components are seen, reflected in, objectified by, and instrumentalized by the observer or subjective self.

Sexual dimorphism – when (usually adult) males and females of a species present different physical appearance and/or behavior. Some sexual dimorphisms are transient and only appear during breeding season.

Small Multiples – a graphic design technique to invite and reinforce comparisons, in which two or more images are presented adjacent to each other, all identical except for changes in one variable.

Species distribution – where a species occurs in geographical terms, e.g., “Gulf States and east coast of North America to Maine”.

Spirituality – the quality of finding meaning and purpose in existence.

Subject-Object Dualism – the philosophical assumption, when an individual is thinking or perceiving, that the thinker and the object of thought, the perceiver and the perceived, are totally separate and independent entities

Succession – ecological succession is a fundamental concept in ecology that states that there is a definable sequence of stages through which an ecosystem will pass. The very early stage of an ecological succession may be a bare rock slightly covered by moss, or a mud flood slowly being colonized by a grass. Usually, this stage shows very low diversity. A mature ecosystem will on the opposite, frequently show high diversity of species, many mutualistic interactions, and a high degree of nutrient recycling.

Task-Commitment – a capacity for high levels of interest, enthusiasm, hard work and determination in a particular area of endeavor.

Taxonomy – the classification of organisms into biological units, such as species, genus, and family.

Theoria – an Aristotelian ideal of contemplation that utilizes the highest application of reason.

Values – internalized beliefs or belief systems that shape behavior, often transmitted culturally, and typically acquired in early childhood or at certain critical periods when an individual is particularly susceptible to environmental influence.

Visual cognitive map – a graphic representation of concepts and relationships as they are understood by the map-maker. A student's concept map would be such an example.

Visual confection - a mélange of juxtaposed scenes within an image, or images-within-an-image, such that the viewer must draw upon knowledge and/or imagination to give meaning to the image.

Visual Lie - occurs when visual drifts in scale within an image have magnifying effects upon the expectations and perceptions of the viewer (Tufte, 1983).

Visual Literacy – the ability to discriminate and interpret the visual actions, objects, and/or

symbols, natural or man-made, that are encountered in the environment, to be able to communicate visually, and to comprehend visual communications.

Willughby and Ray – two Englishmen recognized as the first modern systematists, who traveled together through Europe in the 17<sup>th</sup> century, collecting information about and pictures of natural history subjects, including birds, and also devised a rudimentary classification scheme for birds based upon bill form, body size, and foot structure.

## CHAPTER 2: LITERATURE REVIEW

### Characteristics of Scientists and the Development of Scientific Careers

#### The Game of Science: Characteristics and Issues

Science has been characterized as a game played by professionals (McCain & Segal, 1989), the diverse attractions of which include diversion, intellectual stimulation, social interaction, completion, chance, strategy, emotional gratification, and curiosity. Participants in this game – scientists – are overwhelmingly characterized by curiosity, a character trait that motivates the search for - and the discovery of - new information. A new scientific project connects the scientist to the material under investigation on both the emotional and the intellectual levels, as he or she either understands or generates an idea and speculates upon possible alternatives. During the period of investigation and discovery, the scientist's world is uncertain, fragmented, and incomplete, and the imposition of order upon chaos becomes a pressing matter. The rewards of completion are momentary, for every advancement and solution tends to generate another question or problem. Many scientific discoveries have more than an element of serendipity, and ideas arise with apparent spontaneity, although much thought and observation usually underlies such phenomena. Although progress in science is important, frequently having significant and widespread effects, the game analogy is useful when attempting to understand scientists as the participants in this game.

Characteristics of a scientist tend to be independent of the particular discipline, or field of science (Busse, 1984; Ciechanowski et al., 2004; Lipscomb, 1995; McCain & Segal, 1989). Attitudes and values – or worldview - are more important and predictive than specifics of practice. The scientific attitudes are particularly exemplified by the approach to problem solution. Since problems in science rarely yield to frontal aggression, but demand subtlety and



patience, the scientist must be tolerant of considerable ambiguity and frustration for extended periods of time. Another personal requisite is a degree of persistence extending to the point of stubbornness, for scientific theories must be anchored in extensive and detailed observation.

The solution of scientific problems also frequently demands an unconventional approach, thus the scientist departing from 'normal science' (Kuhn, 1962) requires a high degree of independence and intellectual autonomy. The work of Mansfield (1984) and McCain and Segal (1989) implies that the personalities attracted to and successful in science are thus selected for by the nature of scientific problems. Not all such problems require a revolution in thinking, however. Many tasks of basic science fall within the parameters of normal science, requiring the articulation, derivation, and generation of principles that have explanatory power; work that often consists of articulating such details within a pre-existing conceptual schema. Such a conceptual schema contains both the explicit and implicit ideas that govern thinking about a specific natural phenomenon. Investigation of a part of nature within a conceptual schema – such as a taxonomic framework – absorbs more scientific effort than any other single activity, adding clarity and precision to existing principles (see Lipscomb, 1995; Williams, 1994).

#### Issues Relevant to the Personal Characteristics, Career Choices and Development of Scientists

Certain issues have directed an extensive body of research on the characteristics of scientists and their career development (Busse, 1984; Eiduson, 1973; Lipscomb, 1995; Rubenstein, 1997; Williams, 1994):

- (1) Conditions of background and early life experiences that encourage an individual to select science as a career.
- (2) Necessary personal qualities of a scientist, and the response to life events given these resources.

- (3) Relevant experiences, attitudes and interests that appear to lead to careers in science.
- (4) Conditions and stimuli that might precipitate the decision to become a scientist.
- (5) The processes of socialization into a scientific career, whereby values of that profession become internalized, and a scientific identity is acquired.
- (6) Choices faced by a scientist in terms of roles and behaviors, and the extent to which such decisions are predictable from an individual's background and previous life experience.
- (7) The extent to which productivity and creativity in science can be predicted.
- (8) Developmental paths of scientific careers, and the factors influencing this path.
- (9) Identification of the rewards and frustrations of careers in science.

Studies examining such topics have employed both personality and socialization approaches (Busse, 1984; Ciechanowski et al., 2004; Eiduson, 1973; Rubenstein, 1997). The personality model emphasizes personal characteristics and common experiences that support or thwart interest in science, and the motivation to pursue a career in this field. Activities, experiences, and relationships tending to lead an individual into a life in science have been explored. These studies imply that work life decisions reflect the outcomes of previous life events, and are an attempt to replicate and/or intensify previously rewarding outcomes (e.g., Cattell & Drevdahl, 1955; Ciechanowski et al., 2004; Eiduson, 1962; Gill, 2004; McClelland, 1962; Parloff et al., 1968; Van Zelst & Kerr, 1954).

The socialization model also utilizes a developmental perspective (Ciechanowski et al., 2004; Eiduson, 1973). Here, social reward systems that delivered gratification in early life stages become modified and elaborated in later life, encouraging the development of new abilities and motivations to meet the demands of new learning, and increased expectations of others.

Individual life goals are continuously revised in the face of new learning and new demands (e.g., Busse, 1984; Eiduson, 1962;; Roe, 1957) .

The psychological literature has generally classified scientists into two groups: professional - typically postdoctoral – practitioners, and fledging scientists (typically undergraduates and high school students). It has been commonly assumed that data from these two populations would show something of a cause and effect relationship; that studies of established or eminent scientists would yield data on identification of likely success in fledging scientists, and that studies of fledging scientists would show characteristics – albeit in immature or developmental form – of successful and established scientists (e.g., Chambers, 1964; Eiduson, 1962,1973; Knapp, 1963; Maloney, 1990; McClelland, 1962; Schaeffer, 1967; Tyler, 1964; Williams, 1994).

The predictor variables that are thought to predispose an individual to pursue a life in science are: family background, childhood events (especially those relating to academics), and intellectual and emotional characteristics of the individual (Busse, 1984; Ciechanowski et al., 2004; Eiduson, 1973; Rubenstein, 1997). Results from studies of family background and environmental variables have been conflicting (e.g., Astin, 1963; Clark, 1957; Knapp, 1963; Roe, 1953) but one conclusive finding that has emerged is that scientists, particularly creative scientists, have been permitted greater autonomy as children (Datta & Parloff, 1967; Rubenstein, 1997; West, 1960; Williams, 1994). A related finding is that family ties, while not disrupted, are not reported as especially close in the childhood homes of those who become scientists, and relationships within the home have been characterized as stable but lacking in warmth (Bush 1969; Busse, 1984; Ciechanowski et al., 2004; Eiduson, 1962; Roe, 1957). Thus the characterization of an ideal childhood environment as warm, supportive, and closely knit for the development of curiosity, independence, and maturity does not seem to be valid for the

production of natural scientists. Eiduson (1973) speculates, “perhaps it is the very absence of nurturant and security-giving family background that fosters the initiative and resourcefulness that scientists show” (p 9.)

Studies of childhood interests as predictors of a career in science have yielded fairly conclusive results (Eiduson, 1962; Lipscomb, 1995; McClelland 1962; Schaefer, 1967; Williams, 1994). Satisfaction from intellectual and scientific activities (such as reading and mechanics) appears early and become focused. Scientific interests in boys who become scientists are generally crystallized by the eighth grade, with the 10 to 14 year old period being especially important in the development of these interests. Few interests in natural science appear after age 14 in boys (Tyler, 1964; Williams, 1994). Girls tend to develop scientific interests in their high school years or even later (Eiduson, 1973; Lipscomb, 1995).

In terms of academic performance, scientists tend to show motivation and ability throughout grade school and high school, and by the seventh grade, skills predictive of creative scientists can be identified (Chambers, 1964; Eiduson, 1973). Natural scientists have overwhelmingly identified their major area of profession interest by the time they enter college (Busse, 1984; Eiduson, 1973; Gill, 2004;). In terms of choice of institution, it appears that good undergraduate and graduate programs and superior science students seem to find each other, although the question of whether good scientific institutions select or attract superior students, or superior candidates initiate the choice of college remains confounding. The evidence indicates that the students select the program or institution, which then tends to rise to the caliber of the students, and also that teachers who are masterful, warm, and intellectually eminent attract promising science students to institutions and courses of study (Eiduson, 1973; Gill, 2004; Knapp, 1963).

Studies of the personality dimensions of scientists reveal an interest in objects and phenomena rather than people and personal relationships, somewhat loose controls on behavior; an acceptance of challenge, possession of an unusual degree of drive and task-commitment, and considerable ambition, confidence, and self-esteem (Busse, 1984; Eiduson, 1973; Lipscomb, 1995). Personal autonomy and intellectual freedom is a non-negotiable value of mature scientists that has emerged in many studies (e.g., Busse, 1984; Ciechanowski et al., 2004; Cattell & Drevdahl, 1955; Eiduson, 1962; Stein, 1963). A composite portrait of a mature and successful scientist reveals an individual who would be characterized as adventurous and a risk-taker, an independent and self-sufficient producer who places a high value on autonomy, who is enthusiastic about work, and is perceived as a dominant personality (Busse, 1984; Cattell & Drevdahl, 1955; Eiduson, 1962; Lipscomb, 1995; McClelland, 1962; Parloff et al., 1968; Van Zelst & Kerr, 1954). Such characteristics presumably serve to enhance intellectual capabilities, and studies also indicate that a high proportion of the most capable and creative scientists are withdrawn and introverted (Cattell & Drevdahl, 1955; Ciechanowski et al., 2004; Drevdahl, 1956; McClelland, 1962). Eiduson (1973) speculates that such personality characteristics are valuable to science, permitting intense persistence, reduction of distractibility, and providing a “kind of defensiveness or paranoid thinking that resists too easy acceptance of the obvious” (p. 12).

Systematic studies of the intellectual aptitudes and endowments of personality with which a potential scientist meets academic experience indicate that highly superior intelligence – as measured on standardized tests – does not appear to be essential for a researcher. Mature scientists rated as displaying outstanding creative abilities encompass a wide range of scores on such tests, from high-average to genius categories (Barron, 1969; MacKinnon & Hall, 1971).

Examination of the motivational elements in the intellectual performance of scientists consistently indicate an orientation toward intellectual stimuli, engagement with novel and unusual concepts, an interest in fantasy, attention to sensory impressions along with a developed capacity for observation, and high tolerance for ambiguity (Bruner, 1962; Busse, 1984; Eiduson, 1962; Frenckel-Brunswick, 1948; Holt, 1970; Lipscomb, 1995; Williams, 1994). Scientists' thinking is further characterized by verbal facility, fluidity, flexibility, and a capacity for abstract and symbolic thinking, along with an ability to loosen intellectual controls without anxiety or disorganization (Busse, 1984; Ciechanowski et al., 2004; Andrews, 1965; Drevdahl, 1956; Kris, 1951; Mednick 1962). Cognitive abilities such as these permit perceived reality to be transcended, and to serve as a point of departure in the scientist's thought processes.

The intellectual orientation displayed by established scientists as described above has also been observed in adolescents (Taylor & Ellison, 1967). Fledgling scientists such as these display unusual dedication and commitment to scientific activities at the expense of other pursuits (see Cattell & Drevdahl, 1955; Eiduson, 1962; Lipscomb, 1995; Roe, 1957; Taylor & Ellison, 1967; Williams, 1994). Parloff et al. (1968) found that creative adolescents resemble creative adults and differ from less creative populations of all ages in characteristics such as assertiveness, self-confidence, and autonomy, an assertion reiterated by Gardner (1993) and Piirto (1998). Other characteristics defining established and potential scientists were less consistent, leading Ciechanowski (Ciechanowski et al., 2004) and Eiduson (1973) to conclude that as the scientist develops, he capitalizes upon some characteristics advantageous to his work, and suppresses those that are unhelpful. Some characteristics of personality may also not appear in every developmental phase, or may be transitory - the stability and persistence of intellectual and personality traits over time is difficult to investigate and remains little understood..

Understanding of the mechanisms or processes that lead to the choice of a scientific career is mainly dependent on the theory of vocational choice. The factor-choice approach developed by Holland (1966) and later embellished by Campbell (1990) organizes personalities into six categories – realistic, intellectual, social, conventional, scientific, and artistic – and formulates six model environments. In the schema of Holland and Campbell, the development of a personality type that permits organization of individuals along career lines, involves the preference for certain activities that in turn encourages the development of competence in those areas. With respect to the scientist or investigative type, a combination of genetic traits and environment lead to a preference for activities entailing the observation and investigation of natural phenomena. These preferences lead to an acquisition of scientific competency and a preference for investigative occupations and a corresponding avoidance of enterprising or persuasive roles (Lipscomb, 1995; Gill, 2004; Janovy, 1985/1996; Williams, 1994).

There is no existing model for the development of a professional career in science that has been conceptualized from empirical data on scientists (Busse, 1984; Eiduson, 1973;). However, studies on relevant variables suggest that if intellectual capacity is sufficient, and such abilities are rewarded and reinforced by early experiences, interests, personality, and motivational factors become important. Exposure to scientific research and scientific experience is also somewhat predictive.

Some social learning theorists (Becker, 1964; Becker & Carper, 1956) maintain that career choice as a distinct conscious phenomenon does not actually occur, and that movement toward a career emerges gradually through a constant narrowing of down of interests, skills, and preferences of childhood and adolescence. However, most scientists can specify a time at which

they decided to pursue science, and natural scientists almost always have decided upon their career path prior to college (Eiduson, 1973; Janovy, 1985/1996; Lipscomb, 1995; Straus, 1965; Tyler, 1964; Wilson, 1994). Early commitment to science may be encouraged by research experience or by teachers and influential mentor figures; Krippner (1963) noted that teachers are stronger influences than are parents in directing students toward science. The research experience presumably gratifies both emotional and intellectual needs for certain activities and values, for vocational decision embodies personality (e.g., Cattell & Drevdahl, 1955; Ciechanowski et al., 2004 ; Eiduson, 1962; Holland, 1966; Lipscomb, 1995 ; McCain & Segal, 1989; Roe, 1953, 1957, 1963; Williams, 1994).

The decision to become a biologist – specifically a naturalist –and the developmental patterns of career following such a decision will be examined later. Taking a broader view of scientific careers, Eiduson (1973) commented that the academic opportunities offered to a student and the motivation toward schooling are more influential in the choice of natural science as a career than in applied sciences or social sciences, a generality confirmed by Busse (1984). In terms of the ways in which scientific careers tend to evolve, and how scientists choose to invest themselves, certain career lines have been delineated (Eiduson, 1973; Gill, 2004). There are career stages that are invariable, and those that are more fluid, in addition to critical periods for decisions and mobility.

Scientific performance, achievement, and career course are also related. Periods of maximum productivity (measured by publication rate) are directly related to the effort devoted to research (Andrews, 1965; Busse, 1984), and productivity is lessened if administrative or teaching duties take precedence (Eiduson, 1966; Dragstedt, 1962; see also Janovy, 1985/1996). The PhD granting institution appears to be the most important factor influencing horizontal and vertical



mobility within academia, even controlling for productivity of the scientist (Gill, 2004; Hargens & Hadstrom, 1967).

Scientists vary in their preference for theoretical or experimental or practical approaches to research. Some prefer to initiate ideas, some to formulate problems, while others are intrigued by methodology. Gough and Woodworth (1960) elaborated upon eight types of scientist identifiable by strengths and preferences in research roles. They found that stylistic research types such as the 'methodologist', 'zealot', and 'innovator, which were obtained on the basis of Q-sorts related to activities, could be correlated with personality as measured on the California Personality Inventory. This suggests to Ciechanowski et al.(2004) and Eiduson (1973) that personality differences may also be instrumental for the niche into which a scientist moves.

McCain and Segal (1989) classified scientists as players, operators, or bystanders, according to their intrinsic motivations for pursuing their careers, and the roles they inhabit within the field. Players are motivated by the intrinsic pleasure of playing the game, particularly by curiosity, the stimulation of uncertainty, the aesthetic pleasure of making an original observation or creating a new idea, the contest with nature, and intellectual stimulation. Such scientists have much in common with explorers, philosophers, and artists. Operators are motivated to a greater extent by the extrinsic rewards of science, primarily recognition and material benefits. Such scientists are frequently extremely productive, though less intellectually gifted than players, and are often highly visible as administrators. Operators and players are not mutually exclusively classifications, and players may also be found in administrative positions, although frequently out of a sense of obligation, and deriving less enjoyment from such roles. Bystanders may be highly trained and competent scientists, but choose not to participate actively in research, tending to shift to nonscientific or marginally scientific pursuits inside or outside the

intellectual community. A shift to art or philosophy is not uncommon, and such individuals may become more interested in disseminating knowledge than adding to it – as teachers, writers, or illustrators (Janovy, 1985/1996).

Scientists – although characterized by independent personalities and placing a high value upon autonomy – frequently engage in extensive professional collaboration. The productive scientist is found to interact with colleagues (Busse, 1984; Pelz, 1967), and spends as much as a third of his time in discussions with colleagues (Busse, 1984; Hagstrom, 1965). A strong association between colleagues serves to concentrate energies, and results in greater productivity and more recognition than for the individual who works alone (Busse, 1984; Price, 1963). Following this hypothesized “invisible college”; Crane (1969) found that networks of relationships that develop between individuals working in a specialized area bring scientists into intense relationships with each other. Patterns of collaboration vary with the stage of career development; eminent scientists have been found to engage in more collaboration at every stage of activity (Busse, 1984; Zuckerman, 1967).

With respect to the productivity and creativity of scientists, peak periods of professional work of lasting impact have been shown by one analysis to occur relatively early in a professional career, when scientists are in their twenties and thirties (Lehman 1960a, 1960b). However, another retrospective analysis of productivity and creativity showed that 19<sup>th</sup> century scientists produced half their output after age 50 (Dennis, 1954, 1956; Lipscomb, 1995). Studies of eminence (Eiduson, 1966; Gardner, 1993; Lipscomb, 1995; Piirto, 1998; Roe 1957, 1963; Williams, 1994) support these results, finding that no reduction in output among prominent scientist occurred until age 60, and that productivity tended to be maintained fairly evenly over time. Yet the most original work in natural science is popularly associated with the late twenties

and thirties, purportedly before the scientist becomes invested in paradigms and doctrine (Eiduson, 1970; see also Janovy, 1985/1996).

The effects of achieving eminence – defined as recognition and respect from colleagues – and the factors associated with such success have been the target of a number of psychological studies (Busse, 1984; Clark, 1957; MacKinnon, 1965; Roe, 1953; Wispe, 1963; Zuckerman, 1967). More eminent scientists have a stronger professional commitment than less distinguished colleagues, and are not particularly altruistic in their motivations. They start careers earlier, are exposed to research earlier, and their intellectual drives were generally encouraged and gratified at an early stage by parents, teachers, and family friends. The time of active publication is extensive and they become associated with major universities early (Busse, 1984; Zuckerman, 1967).

Once recognized within the domain, scientists are subject to the ‘Matthew Effect’: a powerful mechanism operating within the community of science; whereby persons who receive recognition continue to do so (Cole, 1970; Merton, 1968). Achieving recognition brings in its wake greater demands for lectures, organizational, and administrative and advisory commitments, which tend to lead the scientist out of his primary area and initially result in a decrease in productivity (Straus & Radcliff, 1969; Zuckerman, 1967; see also Janovy 1985/1996). In addition, new avenues open up that are more enticing to a scientist disinclined to stay in the laboratory or within the confines of academia, and the assumption of a different role is often driven by neglected values assuming new priority (Eiduson, 1973; Gill, 2004; Lipscomb, 1995).

Environmental factors are equally important determinants of scientific performance as are aptitudes and personality factors. Pelz (1967) and Andrews (1967) describe a “creative tension” associated with optimal scientific performance, also discussed by Janovy (1985/1996). Creative

tension emerges from working conditions that include both sources of stability and confidence, a degree of autonomy that stops short of isolation, and disruptive tensions in the form of the amount of time available for research and the extent of interaction with colleagues. The optimal combination of security and challenge was found not to be identical for all scientists; maturity, experience and role of the scientist influenced the best situation for achievement. For example, intellectual freedom has generally been considered necessary for innovative science, and the academic milieu appears most suited to this condition. However, tension often generates achievement and impetus to innovate has often increased in conditions of marginal intellectual autonomy (Busse, 1984; Gordon & Marquis, 1966).

The data available on the characteristics of scientists, and the development of scientific careers have been obtained through studies of varied and divergent populations, in terms of the sub-discipline of science, the degree of demonstrated “creativity” and the degree of career development attained. There is a need for thorough studies of sub-populations, so that meaningful portraits of these groups might shed light upon the validity of these more heterogeneous studies (Ciechanowski et al., 2004; Eiduson, 1973; Lipscomb, 1995; Williams, 1994). One such population is those biologists of the ‘naturalist’ tradition.

#### The Role, Function, and Characteristics of the Expert Naturalist

##### Naturalists as a Subculture within the Scientific Community, and a Consideration of the ‘Naturalist Intelligence’ and ‘Biophilia’

Professional and amateur naturalists comprise a subpopulation of biologists concerned with understanding the natural world at the level of the organism and of its local ecology (Janovy, 1985/1996). These individuals do not subscribe to the paradigm shift in biology of the last half-century, where the biological scientist functions as an engineer and manipulator of living matter. They continue to regard the role of the biologist as an observer, albeit a skilled and

knowledgeable observer capable of sensitive interpretations, and sometimes piercing insights into the nature of life on earth. Professional naturalists have now become the rebels of the biological disciplines, disdaining the view that the purpose of science is to advance the dominance of humankind. Rather their efforts are addressed to descriptions of ‘inconsequential’ species, and understanding the relationships between these species and their immediate environment, eschewing the emphasis on experimental methods and hypothesis testing as the sole road to truth in biology. This naturalist approach is essentially value-driven rather than methodologically oriented and is rooted in a particular and peculiar view of both science and life.

The notion of the ‘naturalist intelligence’ is one of a number of culturally valued human abilities identified by Howard Gardner (1983/1993, 1999). Gardner’s recent definition of intelligence is a “biopsychological potential to process information that can be activated in a cultural setting to solve problems or create products that are of value in a culture” (Gardner, 1999, pp. 33-34). Thus a particular intelligence is a genetic and/or neural potential possessed by an individual, which depends for its ultimate degree of expression on a variety of cultural and environmental factors (Gardner, 1999). The full expression of the intelligence, from the status of novice to expert in a relevant field, is incrementally developed, and frequently requires a lengthy period of skill acquisition, even under the most favorable of cultural, educational, and family conditions (Gardner, 1983/1993; 1999).

The naturalist intelligence as described by Gardner (1999) is manifested as an extensive knowledge of the living world, and in the expert recognition of plants and animals of the environments familiar to the naturalist. Rachel Carson, John James Audubon, Charles Darwin, E. O. Wilson, Steven Jay Gould, Ernst Mayr, and Louis Agassiz exemplify persons possessing a highly developed naturalist intelligence (Gardner, 1999). The naturalist’s fundamental skill is

hypothesized to arise from highly sensitive perceptual abilities, manifesting as the ability to distinguish between species of organisms and to perceive relationships among those species. In addition, Gardner posits that the developed naturalist is a highly developed biophilic (see also Kellert, 1993; Wilson, 1984).

Biophilia is the innate tendency of human beings to focus upon life and lifelike processes, producing a desire to explore and affiliate with the natural world, and requiring an involved and extensive period of cognitive development (Wilson, 1984). The biophilic may pursue a formal intellectual interest in ecology, but the drive to do so is innate. The degree to which interest is formally developed is dependent in turn upon the potential of the naturalist intelligence in the individual, and the degree to which conditions supporting this development are present (Gardner, 1999).

For the individual who is truly in the grip of biophilia, “every species is a magic well” (Wilson, 1984, p.19), echoing Karl von Frisch’ statement that the study of any single species contains within it the challenges of all the mysteries of life (von Frisch, 1967). Charles Darwin spent forty-four years of his career observing and pondering earthworms (Quammen, 1988). The name of Barbara McClintock is synonymous with the phrase “a feeling for the organism”, an affiliation with maize plants that fueled years of patient observation, ultimately yielding groundbreaking insights and the discovery of jumping genes (Keller, 1983). These examples represent individuals in which the naturalist intelligence and biophilic tendencies combined with suitable developmental conditions to produce eminent scientists.

Biophilia and the potential of the naturalist intelligence are not necessarily the provinces of the eminent or the professional biologist, however. Some degree of biophilia is present in almost all individuals (Kellert & Wilson, 1993; Wilson, 1984), and as Leopold (1966, p.266)

qualified, the average citizen does not require years of formal education before he can ‘see’ his country. However, a special satisfaction is offered to those with enhanced knowledge and understanding of the organisms they perceive. This is the ecologicistic-scientific dimension of the biophilic tendency described by Kellert (1993), the full development of which implies a certain set of ‘naturalist’ values (Janovy, 1985/1996) and a lengthy period of skill development (Gardner, 1999).

Janovy (1985/1996) implicitly takes the existence of the naturalist intelligence for granted, believing that a lifetime of intellectual focus on organisms is driven by “curiosity and desire” (p26), dictating the initial inclination to study a particular organism at an unusually young age. He focuses attention on the worldview (values) of naturalists, and the means by which these values are internalized, particularly those at odds with prevailing cultural norms. Janovy’s characterization of the naturalist is akin to that of the scientific player described by McCain and Segal (1989). The naturalist is portrayed as having a distinct worldview, placing little significance upon professional or material rewards, disregarding institutional politics, and centering his or her reality around the chosen organism or group of organisms. He writes of one professor at the University of Oklahoma: “His world was that of the invertebrates; Machiavelli did not exist” (Janovy, 1985/1996, p.x).

Such passionate and single-minded individuals see whatever problem they are working on as a grand challenge of life, rather than a route to a degree or publication. Theirs is a pure intent that is not necessarily common to scientists in other disciplines. Unconcerned with convention, biologists in the naturalist tradition study what inspires them with little thought of practical applications (Janovy 1985/1996). An extreme degree of independence from social, cultural, and professional conventions is also characteristic of the naturalist orientation, as is a

pragmatic approach to carrying out studies, and a general unconcern with logistical limitations. Janovy does not portray the naturalist as a driven individual, except in the pursuit of biological problems. This self-sufficient and pragmatic approach is conveyed by a recollection of the climate at the University of Oklahoma Zoology Department in the 1960's: "First, you didn't whine because there was no money. Instead you drove your own car, used your own shotgun to collect, and studied what problems nature would allow. Second, a microscope that was good enough for Ronald Ross to solve the malaria life cycle in the 1800's, and thereby receive a Nobel Prize, was damn well good enough for a grad student in 1960. After all, it wasn't the microscope that made the scientist; it was what you chose to look for with it. Third, you didn't get all undone by disappointment or failure. Instead, you shrugged it off and went about your work" (p.xiii).

This characteristic approach of a naturalist to his work has many historical precedents and remains essentially unchanged today (Janovy, 1985/1996). The naturalist, although driven by his problem, is relaxed and pragmatic in his approach. He is flexible, creative, inventive, patient, and undeterred by failure: dispositions that are essential to, and reinforced by, fieldwork. Such individuals also typically take a wide view of what constitutes legitimate biology, avoiding the provincialism of the specialist, and are enabled to see applications for their own observations and discoveries that may not be obvious to a more narrowly focused person. Work centered around organisms in their natural habitat also tends to produce considerable humility in the student, for "complex biological problems are great equalizers" (Janovy, 1985/1996, p. xiii).

Naturalists differ significantly from many scientists by not being anthropocentric in their worldview, regarding humans as only one of many millions of species occupying the planet, and not therefore worthy of special interest (Janovy, 1985/1996). This is in stark contrast to the



values maintained by many other professionals, and these naturalists may appear somewhat eccentric as they tend not to be consumed by human conflicts, activities, and desires. In ecological terms, human beings are no more than effective competitors for resources. As individuals, naturalists share one common vision – their identity is rooted in what they perceive as important in their surroundings. This may explain the discomfort of naturalists with administrative positions, in which they are forced to adopt and live with a set of conflicting values.

Values are cultural phenomena, and are mostly acquired in early childhood. The question that necessarily arises is why the naturalist internalizes a set of values at odds with those prevailing in his culture. Janovy's summary of the literature on the acquisition of values emphasizes that: there are critical periods in early childhood when the individual is especially receptive to certain environmental influences - that early experiences often shape later beliefs and thus behavior (Janovy, 1985/1996, pp.4–5). Once established, such belief systems or values are unlikely to change.

Concerning the mechanisms by which the naturalist's worldview is acquired, Janovy (1985/1996) believes that a distinct mode of perception; a biological awareness (an awareness that is implied by the concept of the naturalist intelligence), is a necessary pre-existing condition. The vision of the potential naturalist is initially directed and led by a sense of awe and wonder with respect to the natural world. Most children are curious about nature, but those who become committed naturalists possess this characteristic to a much greater degree. A fascination with observing organisms appears in early childhood, along with a more unusual tendency to process and reflect upon these observations (see comments on early experiences later in this section). A special sensitivity to biological phenomena, and discernment of fine distinctions, is present in the

emerging naturalist, which matures into an “aesthetic seeing” (Dewey, 1934). As the naturalist observes an organism, he goes beyond compartmentalizing and categorizing to develop an empathy that allows the gestalt, or essence, or the organism to be experienced. This aesthetic seeing, along with the development of technical skill in biology, allows for the development of deep knowledge of the organism or phenomenon, and the ability to combine seemingly unrelated ideas. In turn, this deep knowledge yields the ability to “ask the right questions” (Janovy, 1985/1996, p.20) as the naturalist can see beyond surface characteristics into structure, process, and complexity.

Ultimately, the naturalist is able to make original observations, and meld these into a synthesis of understanding. This is the mark of a developed and mature biologist, and often the point at which an individual’s self-perception and identity is irrevocably that of ‘biologist,’ and this identity is then never off-duty – all sensory impressions are incorporated within the biologist mind-set (Janovy, 1985/1996). The metaphors occupying the mind are insistently biological: a vacant lot brings reflections upon stages of ecological succession, a busy metropolis stimulates thoughts of niches and human behavior, and a garden pest raises questions and ideas for experiments.

The naturalist intelligence frequently first manifests as an early disposition to collect natural objects. For example, both Charles Darwin and Thomas Hunt Morgan had extensive collections of stuffed birds, eggs, insects, and fossils before age ten. Biographies of biologists also always indicate early events and influences in which non-human organisms are held in high regard: Janovy’s own first memories concern zoo animals (Janovy 1985/1996). Ornithologist and illustrator George Miksch Sutton cites a man with an extensive collection of bird skins as one of his earliest memories in a long and eventful life (Sutton, 1980), and E.O. Wilson recalls

becoming captured by a jellyfish in the shallows of the Gulf of Mexico at age seven (Wilson, 1984). Before adolescence, a particular organism or group – such as birds, ants, or butterflies – tends to emerge as a particular focus of interest, and this ‘chosen organism’ has an important function in driving intellectual development (Janovy 1985/96; see also Eiduson (1973) and Tyler (1964). Deep knowledge of the chose organism or group develops into the super-sensitivity to dependencies and relationships mentioned earlier, and this knowledge is frequently established by adolescence (Janovy, 1985/1996; see also Sutton,1980; Von Frisch, 1967; Wilson, 1984).

The stage at which the naturalist fixes upon his chosen organism for study is coincident with the appearance of role models. The role-model may be a teacher, family friend, an admired author or illustrator who is willing to offer friendship and advice to a young naturalist, or any available expert in the area of interest (Wilson, 1994; Janovy, 1985/1996; Sutton, 1980; Von Frisch, 1967). The significance of a role model goes beyond technical assistance, functioning in the transmission and affirmation of the naturalist values, in fostering self-recognition of oneself as a biologist, and in validating life-choices - especially important in adolescence. The budding professional naturalist senses in his role models a force that defines who they are, rather than one that tells them what to do. Janovy (1985/1996) believes that this strong identification of oneself as a biologist, and alignment with the naturalist values, “frees a mind to explore the world in a way that is not available to an intellectual larva, but is also required for the production of original work in any area” (p.8) and translates into an active commitment to a life’s work.

Budding naturalists frequently serve an informal apprenticeship under their role models and mentors, of which there may be a series as the individual matures intellectually and gains experience (Wilson, 1994; see also Sutton, 1980). Graduate school may serve as a formal

episode in this series of apprenticeships, but the process typically begins a decade earlier (Janovy, 1985/1996).

Once the naturalist values have been internalized, and the characteristic worldview has been acquired, the importance of role models diminishes, to be replaced by a need for community (Janovy, 1985/1996). The naturalist values are non-negotiable, and there is a need to associate with others for whom these values assume the same primary importance in life. Thus naturalists create an informal community of individuals pursuing their work as if it were of monumental importance, and in doing so, validate their life-choices. Continuous exposure to like-minded professionals yields reinforcement important to those in a somewhat marginal and insecure subdiscipline of biology.

Although the naturalist path is not commensurate with currently accepted notions of success – either within the scientific community or wider society - Janovy (1985/1996) emphasizes that the deep understanding of organisms gained by the naturalist has considerable social and scientific value. Society gains from the serious commitment and focused effort of naturalists, as “society needs the perception, maturity, skepticism, and analytic powers that come from studying something highly complex” (p. 53). Thus this somewhat marginalized subpopulation of biologists actually provides role models for wider society.

Within science itself, the gift of the naturalist worldview is the demonstrated priority given to deep understanding of the material, rather than a narrower focus upon results. The generation of questions and hypotheses is emphasized over other components of the scientific method, leading the scientist back to a comparative approach that has been considerably neglected by more reductionist practitioners of science. Technology should not be confused with science, and the general public especially is liable to this error. Biologists emerge from this

public, and may be susceptible to the same falsehood. “Given the proper equipment and training, it is not difficult to make monoclonal antibodies. What is infinitely harder is to walk through the woods and decide on the basis of your observations, against which antigen you should make monoclonal antibodies” (Janovy, 1985/1996, p.25). This differentiates the worldview and abilities of a technician from a real biologist, and to make the transition, a naturalist’s mindset must be developed, enabling the practitioner to apply his technological tools to the lives of organisms with understanding. The history of science has demonstrated that tools grow dull quickly and become obsolete, while the understanding of a diligently observant naturalist sharpens and deepens (Janovy, 1985/1996).

#### Expert Knowledge: Criteria and General Principles

Ornithological illustrators require a degree of expertise in the following areas – observation, ornithology and natural history, visual representation and the communication of complex information, and also a degree of teaching skill. Thus it is appropriate to review characteristics of expertise and skill acquisition in a general sense, and also the acquisition of expertise in specific domains.

Bransford et al. (2000) define an expert as an individual able to think effectively about problems in a specific domain. When experts are presented with problems, they can make assumptions, give more detailed interpretations, construct explanations for anomalous aspects of the problems, utilize more corroborative evidence, and pose questions and comments (see Sabers et al., 1991; Patel & Groen, 1991; Wineberg, 1991).

External criteria for the independent determination of expertise are relatively easy to apply. Such criteria may take the form of a simple linear ordering, such as the rating system from Class C to Grand Master used in chess, or a nonlinear tree-like hierarchy, such as the

system of certification of specialties and subspecialties used in medicine (Patel & Groen, 1991). Where no such external criteria exist for a domain, the degree of expertise is frequently determined by testing in a controlled laboratory situation (Ericsson & Smith, 1991), but the design of standardized tasks to capture real-life expert performance is difficult, often inadequate, and involves substantial logistical difficulties. Thus in this study, an external ‘social’ criterion is utilized. An expert ornithological illustrator is defined –for purposes of this study - as an individual who has been a principal artistic contributor to a field guide or recognized technical publication.

Expertise is not considered to be a generalized ability, for behaviors typical of expertise tend to become stable as a group only at high levels of specialization (Patel & Groen, 1991) although there do appear to be some common characteristics of experts in different areas, and also in the pattern of development of their particular skills (Scardamalia & Bereiter, 1991). Some domains of expertise are also synergistic with others. Every kind of expertise involves subordinate skills (such as reading and writing), but in some cases, domains of expertise may be so fused (such as scientific and mathematical expertise in some areas of science) that disentangling the contributions of domain knowledge to perceived expertise is confounding.

There are two primary characteristics that are manifested by experts in many domains (Bransford et al., 2000). Initially, there is the acquisition of an extensive knowledge base that affects what experts notice, involving selectivity, the ability to focus effortlessly on that which is relevant to a task or problem, and the organization, representation, and interpretation of the information selected. This expert knowledge base thus includes procedural and declarative knowledge.

Secondly, experts display the ability to apply this knowledge effectively, and to draw upon it in contextually unfamiliar and ill-structured situations. This is not an end-situation, but feeds back into expertise by improving the individual's ability to remember, reason, and solve problems. Unlike novices, who may solve a problem using domain knowledge but frequently fail to learn from the solution, a characteristic of the dialectic between domain knowledge and particular problems in expert thinking and learning, is that the expert pauses and reflects upon the solution of a problem, and uses that particular case to extract generalizable knowledge to add to or change his knowledge base (Scardamalia & Bereiter, 1991). Expert thinking and learning is thus characterized by a high level of interaction between the general and particular, frequently using the particular to enhance their knowledge and understanding of the general. In contrast, non-expert behavior is characterized by a unidirectional flow of information and skills. Thus expert problem solving is characterized by knowledge transformation, rather than the knowledge-telling approach common to novices.

Certain principles key to expert knowledge have been elucidated, each of which has implications for teaching and learning (Bransford et al, 2000). Experts possess improved discernment of salient features and patterns of information in an environment or problem. For example, Wineberg (1991) found that when groups of high school students, and history experts were asked to select visual information that best reflected their understanding of a historical situation, the experts – even the non-specialists in the area under study – were better able to navigate between visual and textual information. These relative experts were better observers, and did not treat visual representations of knowledge as mere resources to corroborate their understanding or knowledge. Rather, they sought to actively learn from the images as they attempted to complete the task (see also Scardamalia & Bereiter, 1991)..

The content knowledge of experts is organized according to a deep understanding of subject matter. Expert knowledge bases are acquired by emphasizing depth of understanding over breadth of information. As information is acquired, conceptual relationships are established and the information is placed within a meaningful framework. Thus knowledge is processed and reflected upon as it is acquired, and subsequent thinking is then organized around big ideas (Voss et al, 1984). This processing and reflection implies a willingness to take time to develop and understanding of an area or subspecialty, and a review of studies of exceptional performance in a wide variety of domains has found consistent support for a general requirement of a decade of intensive preparation within a domain before expert status is achieved (Ericsson & Crutcher, 1990; see also Bloom, 1985; Hayes, 1981; Simon & Chase, 1973). In most cases, the period of preparation takes place during adolescence and early adulthood, although the period of preparation may be initiated at any time during the lifespan, even in individuals whose creative expertise eventually disrupts the paradigms of a field (Simonton, 1996).

This content knowledge is chunked and reflects appropriate contexts (Chase & Simon, 1973; de Groot, 1965; see also Hinton & Anderson, 1981; Reitman, 1976). An entire framework of meaningful knowledge is thus developed, allowing important and relevant information to be rapidly and flexibly retrieved from the knowledge base (Chi & Ceci, 1987; Ericsson & Smith, 1991; Lewis, 1981; see also Howe 1989).

Expertise tends to be domain specific, but the improved approach to learning inherent in the acquisition of expertise in one domain frequently allows experts to progress rapidly when undertaking study of a new area. Such individuals have been named ‘virtuoso’ or ‘adaptive’ experts, differentiating them from ‘routinized’ or ‘artisanal’ experts (Hatano & Inagaki, 1986). This also has implications for transfer of knowledge within a domain; in Wineberg’s (1991)



study of historians and high school students, the historians who were operating in an area outside of their specialty approached unfamiliar material and documents as experts.

Adaptive experts in particular, display a capacity for metacognition, and are able to probe their own limits with considerable confidence. They realize when their own understanding is incomplete, that apparent discrepancies might be the result of their own lack of knowledge or incomplete understanding, and can retreat from initial interpretations to search for deeper understanding of the issues (Brown, 1975; Chi et al., 1987; Flavell, 1973).

Bransford et al. (2000) consider all characteristics of expert thinking to be ultimately due to superior perception, or sensitivity to meaningful patterns of information. Expert perceivers display the ability to retrieve fine distinctions from capture of the overall gestalt, whereas novices must observe and perceive more systematically. This phenomenon operates across various domains, such as drawing (Winner, 1996) electronics (Egan & Schwartz, 1979), medicine (Lesgold, 1984; Patel & Groen, 1991), and in natural history activities (see Fabre, 1998; Janovy, 1985/1996; Wilson, 1984; 1994). This special 'expert' perception might then, be expected to be displayed via the rapid recognition of problem types in ornithology, and also in those of visual representation.

The domain of expert knowledge then, involves the development of organized conceptual schemas, which guide how problems are represented and understood (Bransford et al., 2000). Thus production of an expert involves critical cognitive processes and explicit learning mechanisms. When experts are asked to verbally describe the approach they would utilize in solving a problem, they describe a top-down or funneling approach, in which they refer to concepts, principles, and/or laws first. In contrast, beginners employ a bottom-up or shotgun approach, mentioning details, facts, and the operations in which these would be utilized. The

expert and novice approaches have been respectively described as forward and backward reasoning (Anzai, 1991; Patel & Groen, 1991). Forward reasoning works from the given information to the unknown; backward reasoning works from a hypothesis about the unknown back to the given information. Forward reasoning is knowledge based; backward reasoning is goal-based. However, forward reasoning is highly prone to error in the absence of an adequate knowledge base, since inferences made may not be legitimate. Experts generally revert to the hypothetico-deductive approach (backward reasoning) when solving problems outside their domain of specialized knowledge (Patel & Groen, 1991).

Experts have a formalized schema upon which to draw, and organize their thoughts around the big ideas that structure those schemas. Novices are more concerned with identifying the operations by which they can manipulate facts and details to produce solutions. The expert utilizes a slower and more philosophical approach in which he considers the nature of the problem. It might not even be a problem if correctly identified and placed within the framework of existing knowledge. The novice applies himself to the surface characteristics (superficial aspects) of the problem. Thus not only does the expert take time to build a complex and meaningful knowledge base, he also takes more time than a novice to study a problem (Anzai, 1991; Larkin et al, 1980); Patel & Groen, 1991; Scardamalia & Berietter, 1991).

### Naturalists as Experts

Field experience with living organisms offers a learning situation that may promote adaptive expertise, a model conceived by Hatano and Inagaki (1986). This model presents expertise in the context of a successful learner. Adaptive experts approach situations flexibly and learn new skills and content constantly. They not only use what they know, but have a metacognitive orientation, currently questioning current levels of expertise and attempting to

move beyond them. Time spent observing and studying organisms in a complex natural habitat is likely to force and/or reinforce flexibility in thinking and promote an approach of using current content knowledge to approach situations and problems on their own merits, thus promoting an adaptive or virtuoso approach, where the student of nature is constantly required to use his or her knowledge differently, rather than more efficiently. It is necessary that the expert recognize meaningful patterns of information in the field situation (Bransford et al., 2000; Janovy 1985/1996) and thus begin his problem solving from a more elevated position.

The expert naturalist first seeks to develop an understanding of problems, and thinks in terms of core concepts and big ideas, first focusing on the problem rather than rushing toward an immediate solution. When an expert ornithologist encounters an unfamiliar bird, such an observer will notice characteristics of the bird and its local habit, and then classify the received information in terms of the concepts in his knowledge base, reflecting upon possible relationships. It is important to note that he first spends considerable time studying the bird – or in more general terms, the problem. He selectively retrieves information helpful to the problem; necessarily conditionalized knowledge that is amenable to retrieval. The fluency with which he retrieves information does not place undue stress on his attention, thereby freeing his attentional capacity to focus on the bird. He will possibly pose additional questions to be answered. Metacognition will be utilized during this process, as the expert steps back from his initial assessment of the problem, questioning whether it is overly simplistic, and also whether his knowledge is relevant. In contrast, a novice birder might immediately go to the field guide to give the bird the ‘correct’ name, and thus solve the problem with little processing of observations, spending less time in reflection, with correspondingly less increase in his knowledge and understanding.

As mentioned previously, expertise is generally considered to be limited to singular domains, with little transfer to other domains in most instances (Chi, Glaser, & Farr, 1988). The common perceptual skills involved in the illustration of organisms imply that this field may be an exception to the generalization of limited transfer. Expert naturalists and expert illustrators must both be expert observers. Well-developed metacognitive ability may also be transferable between domains (Holyoak, 1991).

### Expertise in Drawing

The majority of studies concerning the acquisition of expertise in various domains stress aspects of skill development driven by motivation, diligence, and persistent and relevant practice over a timespan of at least ten years (Howe, 1990;1996). The general consensus of research on expertise is that there is little evidence for inherently remarkable aptitudes possessed by experts. Rather, given enough directed practice and reward for achievement, any individual of adequate cognitive ability can reach expert levels of performance in a given domain (arguments summarized by Ericsson, 1996).

Winner (1996) challenges this environmental view of expertise in the domain of the visual arts, making a case for the role of innate talent in drawing expertise, favoring a model of precocious talent linked with drive. She cites a number of studies finding that high achievers in the visual arts have recognized high ability before they begin to work at art intensively (e.g.,, Winner & Casey, 1992; Winner & Martino, 1993). Individuals of ‘ordinary’ ability are less motivated to diligently work at drawing than those showing some precocity in the domain, lacking “the rage to master” possessed by those of talent (Winner, 1996, p.286). In addition, talented artists display different kinds of drawing abilities than do those who merely apply themselves consistently to acquiring drawing skills (Golomb, 1995).

Certain specific attributes displayed by those innately gifted within the realm of the visual arts, compared to those of the diligent but less-endowed student, have been identified (Winner, 1996). First, individuals gifted in drawing show more rapid learning and more motivation to acquire skill, presumably because of the ease, with which learning occurs, and the frequency and intensity of the associated rewards. Second, such individuals show abilities to self-teach and make discoveries within the domain independent of instructional scaffolding (Charness et.al, 1996; Ericsson, 1996). This particular ability appears to derive from these artistically gifted students perceiving in a qualitatively different manner from others, a phenomenon that manifests at a young age (Winner, 1996).

Winner (1996) further speculates that giftedness in the visual arts tends to go unnurtured, if not unnoticed, by parents and schools. As a result, expertise is less common in this domain than in others, such as mathematics, chess, or music. Due to the lack of structured support for their abilities, the artistically talented are more likely than other gifted individuals to disengage from their domain of talent by early adolescence, as competing demands from school, peers, and family dilute their focus (Csikszentmihalyi et al., 1993). This demise of involvement is not inevitable however: “Finally, there are those with both talent and a drive to work that continues undiminished into adulthood. These are the Picassos, the Yanis; in music these are the Mozarts and the Menuhins; in science, these are Roe’s eminent scientists” (Winner, 1996).

#### Implications of Expertise for Education

Ideas about and knowledge of expertise - particularly the expert approach to building a knowledge base by the organization of content around big ideas – has implications for curriculum design. Bransford et al. (2000) maintain that curricula should also be organized around important ideas and concepts, so students learn to organize information in a meaningful

fashion. Understanding of important concepts rather than a superficial coverage of facts can be aided by taking additional time to develop important organizing ideas before moving on to the next topic. Both mathematics and science curricula tend to overemphasize facts at the expense of concept development (American Association of the Advancement of Science, 1989; National Research Council, 1996), offering students a curriculum that is “a mile wide and an inch deep” (Schmidt et al., 1997).

As noted previously, when expert learners build or add to their knowledge base, that knowledge is ‘conditionalized’; it is stored with a specification of the contexts in which it is likely to be useful (Glaser, 1992; Simon, 1980). The expert not only possesses knowledge; he knows exactly when, where, how, and why to apply it. Knowledge that is not conditionalized tends to be inert, because even if relevant, it cannot be easily activated and the fluent and flexible retrieval of the expert is not possible (Whitehead, 1929). Some implications for curricula, instruction, and assessment are that the student should be helped to conditionalize his knowledge if it is to be accessed, and therefore useful. When a fact, concept, principle etc is learned and explained, the student should reflect about when the element of knowledge is likely to be useful. Bransford et al. (2000) recommend the generation of condition-action pairs to assist this conditionalization, important for the solution of the ill-structured problems of the real world. In building expert biological knowledge, for example, learning to identify an organism should not happen in isolation from learning its habitat, behavior, economic importance, etc. Well-structured tests and worksheets are regarded as a possible hindrance to conditionalization of knowledge, for the student is not required to practice consideration of when it is appropriate to utilize knowledge in the ill-structured ‘real world’.

Bransford et al. (2000) further suggest that students might benefit from being presented with explicit models of how experts approach problem solving: that exposure to experts and their thinking might actually encourage the development of expertise in students. However, being taught by an expert in content does not always guarantee transmission of expertise, and may actually inhibit its development if the expert does not possess developed pedagogical technique (Redish, 1996; Schulman, 1986, 1987). Bransford (2000) suggests the use of accomplished novices in such situations, who will be inclined to continually challenge the experts' teaching until their ideas make sense to beginners. On the other hand, many naturalists' biographies and autobiographies point to role models and 'expert teachers' as critical in intellectual and career development, particularly with respect to maintaining interest and developing an appropriate value system (e.g., Janovy, 1985/1996; Sutton, 1980; von Frisch, 1967). However, most such life histories indicate that the 'expert teacher' played a major role in the potential naturalist's life when some degree of accomplishment in the area had already been attained, suggesting that the expert may be indeed best suited to teaching those who have attained the role of expert novice.

A further hindrance to the effectiveness of an expert teaching beginner lies in a faulty perception of an expert by the students. The expert may be seen as one who knows all the answers, rather than one who is capable of constructing or locating solutions. Such a perception is detrimental to learning, placing an emphasis upon appearing competent and infallible, and the Cognition and Technology Group at Vanderbilt (1997) suggest replacing the model of "answer-filled expert" with one of the expert as accomplished student. Such a model is posited to free the student to learn and become an adaptive expert himself.

## Observation: Perspectives of Naturalists, Philosophers, and Science Educators

### The Naturalist Perspective on Vision and Observation

Naturalists have long recognized that observational skill is basic to enjoyment of, and success in, their chosen fields, and have debated issues relating to the acquisition and refinement of this ability for decades. In nature writing, ‘seeing’ as opposed to mere ‘looking’ is represented as a complex interaction between interests, motivation, prior knowledge, and personal characteristics of the observing subject, e.g., perseverance and the willingness to tolerate considerable frustration

Joseph Krutch (1952) believed the viewer is most observant when looking at the novel because of the sense of awe and wonder a new landscape or organism generates. The faculty of wonder generated by the unfamiliar encourages the viewer to spend the time and exert the patience to pay attention to the object of scrutiny, which cannot be summed up and disposed of with a cursory glance. John Burroughs (1992) argues that the observer is more likely to pick up interesting visual details when examining a well-known organism or locality, as did Gilbert White (1886). Both Burroughs and White subscribed to the belief that noticing subtle variation requires prior knowledge of that which is being scrutinized. Aldo Leopold (1953) agreed, but held that interest was the real filter through which fine distinctions became apparent: “The deer hunter habitually watches the next bend; the duck hunter watches the skyline; the bird hunter watches the dog; the non-hunter does not watch” (p126).

Psychologist Rudolf Arnheim (1974) supports the common contention of nature writers that seeing is more than an exercise of our optical apparatus; that a great amount of intellectual exertion is required to truly see, and that what is seen is dependent upon prior experience and interests. Maura Flannery (1998) describes the education of a biologist’s vision that typically



occurs when first presented with technological apparatus that provides more information and detail than the naked eye alone, recalling her own freshman experiences in “wanderings in the microscopic world” (p.2) and the frustrations encountered in first learning to locate and see the cells in an onion root tip – an exercise presented to all beginning biology students. Reflecting upon her early experiences with microscopy, Flannery agrees with Hacking (1981) that we learn to see by doing, not just by looking. Yet mental exertion and persistence alone are not sufficient for educated seeing – where eye and mind constantly interact – when the object of vision is foreign, and the mind lacks a context in which to place the image delivered to the eye. For example, the early microscopist van Leeuwenhoek was a patient and careful visual scribe, producing exquisitely detailed drawings of protozoa, sperm, and bacteria, yet had considerably difficulty making sense of the images he recorded with such care and skill (Elkins, 1992; Flannery, 1998).

#### Philosophical Perspectives on Vision and Observation

All seeing is difficult and complex, and problems in this area are not limited to the microscopist and users of other visual technologies. James Elkins (1996) summarizes the issues and difficulties in the following lament: “No matter how hard I try, there will be things I do not see. No seeing sees everything, and no skill or practice can alter that. Every field of vision is clotted with sexuality, desire, convention, anxiety, and boredom, and nothing is available for full leisurely inspection. Seeing is also inconstant seeing, partial seeing, poor seeing, and not seeing: seeing is also blindness” (p.95).

Such difficulties have been of concern to philosophers for centuries, particularly the major and recurring problem of the lack of integrity inherent in vision. The eye is the tool of the willful self, and exercises considerable selective power as it wanders visual terrain and seeks and

makes choices concerning those objects upon which it will focus, implying that that which is seen is not necessarily truth made manifest (Blumenberg, 1993). In pre-Socratic Greece, the role of contemplation in vision was emphasized, and visionary experience was accepted as indeterminate. The object of vision was not expected to disclose its essence (*ousia*) to a cursory glance or brief inspection. Visual knowledge and truth required persistent illumination provided by patient contemplation over time (Blumenberg 1993; Rapaport, 1993). In terms of the previous discussion of expertise, as the observer becomes educated and visual experience is subject to inner processing, an incremental clarity of perception develops and visual experience incorporates increasing depth and weight.

Beginning with post-Socratic Greek thinking, vision as a route to truth was attainable only through the medium of reason, and the role of lengthy contemplation gave way to that of the mind (Judovitz, 1993). Following Plato's thesis that sensory vision lacks truth, and visual truth can only emerge in the mind, *ousia* was replaced by *theoria*; pure contemplative seeing from which cognition in its highest form emerges (Houlgate, 1993). This was apparently no abstract and incidental objective in ancient Greece: Democritus is reputed to have blinded himself in the pursuit of the discernment of truth unavailable through normal vision.

In the 17<sup>th</sup> century, Descartes was distrustful of sensory vision, rejecting the visible world as actual or potential illusion (Judovitz, 1993). Experiment with lenses, telescopes, and perspective led Descartes to conclude that not only was ocular vision unreliable and arbitrary in nature, but that optics and perspective - both of which have the explicit purpose of allowing the more accurate discernment of nature and art - subject the viewer to further technological untruths. Thus Descartes fled to the deductive method, the systematic connection of causes and events, as less susceptible to error than the limited gaze, reasoning that the trained deductive

mind is less vulnerable to visual misunderstandings than sensory vision, which is inclined to form necessarily incomplete conceptions of reality from mere images.

In *The Philosophical Writings*, Descartes takes the position that signs, words, memories and experiences are intrinsic to the perception of reality, and that vision alone is an unreliable construct (Descartes, 1985). Descartes' theory of knowledge became grounded in distinctions – distinctions formed within mental schema incorporating a multitudinous array of sensations, impressions and processed experience (Judowitz, 1993). In this model, visible properties of objects are transferred into the intellectual domain. Thus an expert in a given area then presumably sees more and also sees more deeply, as he has a fluent and flexible knowledge base as a referent for his sensory impressions.

This rationalist understanding of vision developed by Descartes reached its zenith during the Enlightenment (Kavanagh, 1999). A spectatorial epistemology, in which vision was privileged over other sensory modalities followed, and is retained today. Contemporary academic discourse and colloquial speech remain dominated by visual metaphors as we seek insight and illumination; we get the picture; we inspect and attempt to focus. The very word theory has its origin in the Greek *theoria* – to behold attentively.

The philosophical problem created by rationalism is distancing and the objectification of that which is seen. The phenomenon of distancing – a basic function of sight – creates the belief that viewed objects are distant from and neutrally apprehended by subjects, providing the basis for the subject-object dualism typical of Western metaphysics (Kavanagh, 1999). This inherent neutrality does not allow for the individual filters of interest and motivation with which any individual necessarily perceives his world (see Elkins, 1996; Janovy 1985/1996; Leopold, 1953). Thus the spectatorial epistemology arising from rationalism have been subject to various

critiques over the last two hundred years, and various alternatives to rationalism have been tentatively offered.

The frontal ontology of vision assumed by Western philosophy and science during and after the Enlightenment employs a forceful, focused, and demanding stare, in contrast to the diffuse gaze of the pre-Socratics. Romantic philosophers posited an adjustment to rationalist vision that allowed for the individuality inherent in seeing. Abrams (1953) employs the mirror and lamp as metaphors for the Romantic ‘adjustments’ to rationalism. The rational mind reflects an external object as does a mirror; the Romantic mind functions as a lamp, casting an interesting glow and creating shadows requiring individual interpretation.

Nietzsche was the first writer to mount a philosophical attack upon ocularcentrism, and belittled the passive and indiscriminate use of vision, describing reductionist vision as operating with a lack of selectivity and reducing all that is offered to it to homogeneity (Shapiro, 1993). Nietzsche’s alternative conception of vision was an active and engaged mode of seeing, requiring deliberate and prolonged interaction with the visible world. This “aesthetics of presence” (Shapiro, p. 132), holds that paradigmatic sensory experiences, especially that of visual images and works of art, must also be understood in terms of their success or failure at realizing a ‘full presence’ or manifestation in which nothing is obscure or concealed. The works of some nature writers appear to reflect this intense mode of vision. While the majority of conventional narrators have objectified their characterizations of organisms with which they are intimately acquainted, keeping themselves at a conventional “methodologically and philosophically respectable - and appreciating - distance” (Fritzell, 1990, p.27), there are those at the other extreme - such as Thoreau, Loren Eiseley, Edward Abbey, Annie Dillard, and John Janovy. These naturalists cannot separate their observations of organisms and landscape from their own consciousness,

values, and the meanings they accord to these phenomena and presence themselves conspicuously in their narrations.

Nietzsche accorded a high and almost mystical value to observations of this nature, where vision manifests as a sensory modality serving as apprehension and contemplation to those who have learned to see, despite his critiques of rationalist ocularcentrism and spectatorial epistemology (Shapiro, 1993). In *Thus Spoke Zarathustra*, Zarathustra and the dwarf he has been carrying on his shoulder argue about the visual interpretation of a scene before them – two paths that join at a gateway (Nietzsche, 1978). Here the ‘courageous’ vision of Zarathustra is contrasted with the reductionist and cynical vision of the dwarf – described as *Böse Blick*, or the Evil Eye. Zarathustra demands that the dwarf comprehend the depth and complexity of the scene, but the dwarf obstinately refuses to acknowledge more than two straight paths. Seeing less, or a contentious refusal to see more, is presented as a safer alternative for those – like Zarathustra’s dwarf – who are incapable of courageous vision.

In the 20<sup>th</sup> century, Derrida set out to critique ocularcentrism in *Truth in Painting*, but by claiming that the aesthetic traditions actually subordinate all the arts to speech, implicitly questioned that the hegemony of vision actually exists (McCumber, 1993). Foucault is likewise averse to spectatorial epistemology, portraying the subject/spectator as detached, autonomous, and disinterested yet simultaneously incarcerated by his limited vision, and lamenting the supervisory and dominating nature of ‘the gaze’ (Flynn, 1993). Sartre unconditionally opposes visuality as a source of meaning (Jay, 1993). Although writing on a variety of ocular themes, Sartre’s conclusions of relevance to this study include that: vision is both misleading and insufficient as a tool for comprehending reality, and that vision is always partisan, it has an

agenda, and thus true knowledge cannot be obtained as the looker can only discover answers to questions already formulated.

Another more radical group of philosophers - Merleau-Ponty, Heidegger, Hegel, and Dewey attempted to displace ocularcentrism by transcending the frontal ontology of the post-Cartesian visual paradigm (Houlgate, 1993; Jay, 1993; Levin, 1993). Although critical of the subject/object dualism embedded within reductionist vision, Merleau-Ponty recognized that vision was the supreme mode of communication between an individual and the world (Jay, 1993). Merleau-Ponty identified the ‘empiricist’ and ‘intellectualist’ traditions as two impoverished conceptions of the depth and possibilities inherent in vision. The empiricist tradition reduces vision to observation, assuming that external stimuli merely oppose themselves upon a passive optical apparatus, while the intellectuals posit an absolute subjectivity, which constitutes the perceived world entirely out of the perceiver’s thoughts and judgments. Criticizing both approaches as overly external, construing the world as a spectacle to be observed by a detached and disembodied mind, Merleau-Ponty adopted an alternative that Martin Jay (1993) labels “revelatory illumination” (p.166). Here the viewer mingles with the world, surrendering the ego and offering a pre-Socratic ideal of willingness to let things be, even in moments of active perception. Vision as constituted by Merleau-Ponty is much more than sensory perception: drawing upon experience, adding differentiated information that is then resynthesized on an intellectual level and integrated back into experience, the “eye accomplishes the extraordinary task of opening the soul” to a larger universe (Merleau-Ponty, 1962, p. 186).

Martin Heidegger was highly critical of the visually oriented Greek *theoria*, now reduced to modern empiricism, where all ideas spring – directly or indirectly – from experience (Houlgate, 1993). An essent presents an appearance, from which the viewing subject constructs

an *eidos*, an idea of what the object is. The result is knowledge “based on visual manipulation that is neither objective nor disinterested” (Jay, 1993, p.146) and subject/object estrangement obstructs the full knowledge or development of an idea that might otherwise occur (Kavanagh, 1999). The perceptual matrix is reduced to an ordered grid where the capacity for the infinite is lost (Levin, 1993). Heidegger proposed that an idea was an abstraction of a perceptual object that served as its source and referent, and identified an opposition between being and thinking, where the relationship of thought to being parallels that of subject and object, and understanding follows as a construction of thinking. When the subject views an object with what Heidegger terms the ‘assertoric gaze’, the rigid and predetermined quest for understanding, the result is a straitened and impoverished character of visual experience.

Levin (1993) sees the visual impoverishment resulting from this impassive frontal ontology in terms of figure-ground structures. Under the assertoric gaze, the ground – that space of difference within which the perceptual act may take place – is reduced or occluded altogether. Heidegger likens the ground to a clearing in the forest, where light enters; the light being necessary for and providing the understanding of the scene. Without this illumination from above, the structure of the figure cannot be fully seen and the essent cannot manifest. Assertoric vision rejects the ground, because it cannot be defined, controlled or figured out. In Nietzschean terms, the ground is the abyss.

Although Heidegger believed that the character of vision had degenerated since Plato, “There are still essents ... but the being has gone out of them” (Heidegger, 1961. p.52), he believed – as did Merleau-Ponty - in the potential of the visual (Levin 1993). In order for the ground to illuminate the figure and allow the fullest perception, it must be allowed to “presence as ground, as different from the figures...on which we focus” (Levin, 1993, p.205). This occurs

when the subjects approach to the object is one of *Gelassenheit*; one of letting go and letting be, similar to the pre-Socratic ideal of vision. Thus the redemption of visuality as a route to transformative knowledge lies in a transition from an epistemological to an ontological mode. A number of naturalists writing in the 20<sup>th</sup> century implicitly refer to the value of such a mode of vision (e.g., Dillard, 1974; Fritzell, 1990; Janovy, 1985; Leopold; 1953). Heidegger calls this ontological mode of vision the ‘aletheic gaze’ (Heidegger, 1961, p.154-5), which enjoys multiple perspectives and is aware of context. Aletheic vision occurs when the subject’s approach to the object is one of *Gelassenheit*; one of letting go and letting be, and bears the fruit of deep experiential understanding, in contrast to the one-dimensional knowledge of the correct allowed by assertoric seeing.

Hegel became convinced of the “intrinsic generosity of vision” (Houlgate, 1993, p.107), insisting that the impoverishment of vision lies in the Cartesian insistence on substance and clarity, and the either/or thinking that follows from this. Asserting that vision may actively “point the way to a richer, more open, less reductive conception of thought” (p.106), Hegel held that there is no inherent subject/object dualism in vision that narrows or distorts experience, but only an awareness of light, color, and two-dimensional planes. Spatial depth must be added by touch, and learning substitutes when touch is unavailable, such as when we learn that shadows correspond to depth and distance. It is of interest here to note that the training of many of the finest ornithological illustrators has emphasized touch as an essential component of knowledge, in that many insist upon specimen preparation and dissection as an essential component of deriving knowledge of the character of a species (e.g., Hunt, 2003d; Sutton, 1979, 1980) or have handled live birds extensively as part of research or rescue efforts (e.g., Devlin and Naismith, 1977; Hunt, 2003g; Sutton, 1980). Kellert and Wilson (1993) also imply via a number of cited



case studies that literal ‘hands-on’ experience is a critical component of the development of an expert and committed naturalist.

Hegel held that it is the addition of reflection – reflexive visual consciousness – that introduces the objectification that interferes with pure vision (Houlgate, 1993). Vision cannot bring knowledge when prior knowledge interferes with visual consciousness, thus disagreeing with some naturalists (e.g., Burroughs, 1992; White 1886), psychologists (e.g., Arnheim, 1974), and constructivist science educators (e.g., Trowbridge and Wandersee, 2000). In Hegelian terms, expertise then actually interferes with optimal visual experience (see also Elkins, 1996; Krutch, 1952).

Hegel conceives of optimal or ‘pure’ vision as intuition, where the object is not evaluated with reference to prior knowledge, and the observer escapes the constraints of the self (Houlgate, 1993). Houlgate considers this Hegelian notion of visual intuition as “vision in its full and proper sense” (p.114)), where vision is not narrow and reductive, that which is seen is not approached as an event or object to be “grasped, secured, mastered, and dominated” (Levin, 1988, p.236), but is a mode of openness to experience. Here the object itself guides thinking, rather than the reverse, and the interconnectedness of objects and events becomes apparent; a thesis later reiterated by Elkins (1996). However, Hegel does not hold that visual intuition is sufficient to encounter the world in all its aspects, and argues that full knowledge of the object of vision frequently demands the application of reason (Houlgate, 1993). Thus Hegel is not opposed to thought, merely reflexive thought that diminishes present visual experience.

John Dewey – American pragmatist and contemporary of Heidegger – likewise criticized the spectator theory of knowledge, where human knowledge is held to be analogous to visual perception. Dewey saw the knowledge thus acquired as static and fixed, allowing the knower no

agency, and espoused instead a theory of knowledge based upon perceptual experience (Dewey; 1934/1984; Houlgate, 1993). In *Art as Experience*, Dewey (1934/1984) neither denigrates vision nor accords it any special privilege with respect to other senses, while stressing that vision is a route to wider experience. Vision is described as one of the primary sensory mechanisms by which an organism (or observer) experiences his environment, while perception is the processing of this sensory experience. An aesthetic experience – one presumably common to biological illustrators as they visually consider their subject or subjects – occurs, when subject and environment cooperate to institute an experience in which the two are completely integrated (Ch. 2). This cooperation requires engaged seeing on the part of the subject, and Dewey’s description of the resulting aesthetic experience is not unlike that of the experiential understanding resulting from Heidegger’s aletheic gaze.

Visual activity does not necessarily result in the aesthetic perception that creates authentic experience. Dewey (1934/1984) makes a sharp distinction between identification and recognition, or passive looking versus engaged seeing. Identification merely “nods and passes on” (p.24), labeling objects and events according to category, and such categorization can result only in a diminished experience. The compartmentalization of experiences diminishes the potential of a harmonious life, producing exaggeration in some areas of life and neglect in others. As the human experience is artificially divided, the connections between categories are lost, as the intrinsic meanings of objects, events, and lives become hidden or go unexamined. In turn, as connections are lost, sensations cannot be fully experienced and comprehended, and the life and experience of the perceiving subject (as a categorizing spectator) is diminished. Dewey concludes that such a subject sees without emotion, hears without looking, and becomes aroused without benefit of insight (Ch. 2). Further, he is subject to surface excitation lacking in

transformative potential, and is unnecessarily limited in his possibilities. The meaning inherently embodied in visual experience, that is available to those able to see aesthetically, is lost to the spectator to whom visual experience is restricted to identification, categorization, and labeling.

This same subject remains a complex creature, capable of fine and minute distinctions. His powers of discernment, and the richness of his experiences, are a function of his developed ability to make such distinctions, which Dewey labels as ‘recognition’, a phenomenon qualitatively distinct from identification in temporal terms. The recognition of what is seen is no snap judgment or mere point in time, but is the focal culmination of “long, slow processes of maturation” (p.23). The past and the present are ordered into experience via recognition; for the past becomes meaningful only in the context of the present. Recognition is both necessary in the composition of, and also the product of, meaningful experience. The product of continuity, it is “prefigured in the very process of living” (p. 24). Recognition presupposes deliberation and conscious intent, and it is the addition of this conscious intent to the visual interchange between subject and object that produces experience. This conscious intent or purposes utilizes vision as one road to insight.

The Deweyan conception of aesthetic seeing might be described as a composite of the ideas of Nietzsche, Merleau-Ponty, Heidegger, Levin, and Hegel. In *Art As Experience* Dewey (1934/1984) rescues the potential of vision as an integrated component of knowledge and experience, as he develops a notion of visual connoisseurship, or aesthetic seeing. This pragmatic conception of visually obtained knowledge does not entirely escape the trap of reflexivity, for the world remains bent to the self (Houlgate, 1993), and it does not approach the pre-Socratic ideal of letting the seen be, in the modes of vision sought by Hegel, Heidegger, and Levin. However, Dewey’s notion of aesthetic seeing encompasses Nietzsche’s ‘courageous

vision', where the aesthetically perceptive are 'bold searchers and researchers' rather than apathetic, indifferent, prejudiced and conceited (Nietzsche, 1978). These last adjectives reflect Dewey's characterization of normal vision or inattentive perception, where the meaning and value of objects of vision are not retained as an integral part of the self, and experience is not amplified by visual encounters. Dewey (1934/1984) also tacitly embraces Heidegger's conception that emotion about, and knowledge of the utility of objects, are important components of visually acquired knowledge, and also supports Heidegger's emphasis on the incorporation of the ground, or awareness of the horizon or context, as an object is enfolded into the mental schema. Hegel's 'intuition', or openness to interconnections between objects, is likewise incorporated into aesthetic seeing, as is Levin's ideal of "a gentle form of visual disclosure, where the visual gives serene and certain knowledge" to the observer (Houlgate, 1993, pp. 96-97; see also Levin, 1993).

#### Science Educators' Perspectives on Vision and Observation

The study of art and practice of drawing is one proposed route to seeing in the sense of fully integrating the eye, mind, and emotions in the manner of Dewey's model of aesthetic seeing (Flannery, 1998a; see also Janovy 1985/1996). Perkins (1984) holds that the engaged study of art invokes visual processing skills transferable to many fields of endeavor and Flannery (1998a) argues that such skills are essential to the biologist. Perkins (1984) recommends a four-step method for the study of art, which presumably can also be applied to the study of organisms. The initial step is the allotment of a sufficient amount of time to simply look at a picture. Perkins recommends 10 minutes; a time period also espoused by science educators Trowbridge and Wandersee (2000) for the study of scientific phenomena. This period of time is sufficient for fine distinctions and details to become available to the eye, and is also sufficient for the mind to

focus and initiate the generation of ‘why?’ questions that are essential to scientific endeavor. The 10-minute period allows time for mere looking to interact with thinking and initiate true seeing. Perkins’ second step expands perception by framing questions about the image and making connections, a type of brainstorming in which a painting is thought about in broad terms, on many different levels, and is placed into a variety of contexts, including the cultural, historical, and symbolic (Perkins, 1984). Translating this idea into biological terms, Flannery (1998a) suggests that the student looking through a microscope might ask questions pertaining to the origin of the structure under inspection, its distinctive features and their possible functions, and what still requires a visual ‘uncovering’ for further information. Watts (1975) also describes ‘reading’ a view of a landscape by a similar approach to thoughtful seeing. Perkins’ third step involves thinking more deeply about the observations, and deciding which of these merit further consideration and exploration. Finally, the viewer takes stock, and summarizes what has been learned from the viewing experience, what assumptions he has made, and also refines the questions that will direct further study. Such questions frequently underlie the foundation of fruitful ideas in science.

Perceptive seeing may also be stimulated by the act of recording. Drawing invigorates the act of seeing since thought and drawing have a strong symbiotic relationship (Flannery, 1998a). McKim (1980) feels that our current educational system fails in developing visual thinking and deprives students of a powerful mental tool by emphasizing language and reasoning over visual learning after the primary grades. Flannery (1998) has found that drawing from nature is a method “to see more carefully, to really savor what I am looking at” (p.2). Originally stimulated by the visual journals of Hinchman (1997), Koch (1992), and McLean (1987), Flannery now routinely incorporates drawing exercises into college biology classes.

While philosophers have portrayed the complexities of observation as meaningful vision as a somewhat intangible phenomenon, science educators have attempted to reduce observation skills to a set of discrete proficiencies and have set criteria for the quality of observation. The Norris proficiencies (Norris, 1994) detail three broad areas: making observations well, reporting observations well, and correctly assessing the plausibility and usefulness of observations. Trowbridge and Wandersee (2000) have upgraded these proficiencies to the status of criteria, on the grounds that they form a basis for evaluative standards for assessment in science education. Utilizing a different approach, the Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching (1993) specify five levels of observational competency, from ‘novice’ through ‘advanced’ (p.3).

Trowbridge and Wandersee (2000) stress that careful, direct, and multivariate observation is the foundation of progress in science. *The National Science Education Standards* (NRC, 1996) concur with the respect to the particular importance of observation as a fundamental skill of science that should be consciously and deliberately addressed in the classroom describing observations - along with empirical data – as the central component of scientific evidence (p.117), and stressing the use and value of observation in the approach to science as inquiry (p. 121; p.122; p. 148). The value of observation in science is enhanced when observation goes beyond mere passive seeing, but is rather an active process utilizing many senses, processing, and calling up previous knowledge (Misiti, 1993). Trowbridge and Wandersee (2000) propose their own observational framework for classroom use, utilizing the Norris proficiencies within specific science contexts, where provocation of quality observations is encouraged by specific exercises preceded by cognitive scaffolding that provides the observer sufficient knowledge to make salient observations and then place these within a meaningful context.

## The Nature and History of Ornithological Illustration

### A Brief History of Bird Art and Bird Artists

Those individuals who practice ornithological illustration as a profession – illustrating field guides and other lay and technical publications about birds – may be considered as a representative subset of the naturalist type of biological scientist discussed earlier in this review. A brief history of bird illustration and a discussion of aspects of and influences upon the field is offered below.

Bird painting and illustration is an enormous field, with a history that spans sixteen thousand years, from the oldest known depictions of waterfowl, cranes, eagles, owls and ravens on cave walls in southern France and northern Spain (c. 14,000 B.C.) to tens of thousands of illustrated bird books in existence in the 21<sup>st</sup> century (Jackson, 2002; Pasquier & Farrand, 1991; Talbot Kelly, 1955). A number of influences and themes can be identified in the extensive and complex story that describes the development of bird art. These elements include the maturing of scientific interest through time and the growth of ornithological knowledge intertwined with the social, economic, and political forces shaping the activities of artists of different nations (Farber, 1997; Stresemann, 1979).

The development of painting techniques, availability of materials, and changing technologies relevant to the reproduction of art have been a potent influence in the unfolding of development of bird art, as are the different modes of employment and financial support available to painters of different nations and historical periods (Jackson, 1975, 1985, 1994, 2002; Pasquier & Farrand, 1991; Skipwith, 1979). A most interesting phenomenon is the general absence of formal training for serious ornithological painters, and the informal system of mentoring that took shape in the 17<sup>th</sup> century and continues today. Finally, bird art has always

fulfilled one or more of three functions: the symbolic, the purely decorative, and the didactic or educational. The varying degrees to which each of these functions has been dominant through time and across nations and the extent to which individual painters have adopted or resisted the dominant genre is yet another fascinating subtext of the history of bird art.

The high points of ornithological illustration generally coincide with the vigor of scientific interest and activity at particular periods in given countries, although a dearth of scientific activity has still sometimes allowed for excellence in non-didactic bird painting, if not productivity in book illustration (Talbot Kelly, 1955; Pasquier and Farrand, 1991). Chinese painters from 960 – 1912 AD, their Egyptian counterparts from 4000 BC to around 200 AD, and artists painting for the Mughal emperors in the 16<sup>th</sup> and 17<sup>th</sup> century produced depictions of birds within their artworks that are decorative and/or symbolic in nature (Das 1974; Jackson 2002; Malek, 2003; Talbot Kelly 1955). Nonetheless, these paintings frequently possess considerable scientific integrity in terms of both correct representation of individual birds, the natural co-occurrence of species, and a carefully selected and detailed environment as background, although scientific activity in those cultures was generally lacking (Das, 1974; Jackson, 2002; Malek, 2003; Pasquier & Farrand, 1991; Talbot Kelly, 1955).

During the middle ages of Europe, the illustrators of illuminated manuscripts and psalters also produced some admirable bird painting at a time when scientific activity was almost non-existent (Pasquier & Farrand, 1991; Stresemann, 1975). Zoology was in a depressed state during the middle ages, literacy being the province of monastic scholars. However, the artists employed to work upon the psalters and illuminated manuscripts in the 13<sup>th</sup> and 14<sup>th</sup> centuries appear to have been gifted field observers, since many of the birds depicted are easily identifiable from the miniature paintings (Yapp, 1981).



The origins of scientific ornithology and natural history are first documented in the works of Aristotle and Pliny the Elder, of ancient Greece and ancient Rome respectively. Neither the *Historia animalium* nor the *Historia naturalis* were illustrated works, although Aristotle at times makes reference to existing illustrations (Pasquier & Farrand, 1991; Stresemann, 1975). Pliny's *Historia naturalis* was preserved in monasteries; Aristotle's *Historia* disappeared but was preserved at Thessalonica by Arab scholars, and reappeared translated from Arabic into Latin centuries later. Both treatises contributed to the revival of scientific activity in the Renaissance (Stresemann, 1975).

In the late Middle Ages in Europe, depictions of birds for educational purposes, to convey information about the birds themselves first appeared. Such illustrations were intended to serve ornithology and largely appeared in books (Pasquier & Farrand, 1991). The first of these was *De arte venandi cum avibus* by Emperor Frederick II, which attempted to document the natural history of birds based upon personal observation, free of legend and dogma, and also to refute inaccuracies in *Historia animalium* (Ford, 1993). The illustrations were utilitarian rather than aesthetic, and show the diagnostic features of the readily identifiable birds, with some remarkable similarities to the modern field-guide. Succeeding copies of the book show the portrayals of birds actually becoming more accurate over time, indicating that ornithological awareness was progressing at a local level in Europe during the 13<sup>th</sup> and 14<sup>th</sup> centuries, and also that the artists associated with courts or the church who painted the copies were aware of this new information (Jackson, 2003; Pasquier & Farrand, 1991; Stresemann, 1975).

*De arte venandi cum avibus* was written in the mid-13<sup>th</sup> century, when distribution of new scientific information was poor to non-existent. Although twentieth century ornithologist Edwin Stresemann has called Frederick II “the first great ornithologist known to history”

(Stresemann, 1975, p.9), copies of the book were so few, and communication between scientists so limited, that many of the great Renaissance writers on natural history – Belon, Gesner, and Aldrovandi – were not aware of the treatise's existence, and its potential contribution to ornithology was essentially lost (Jackson, 2002; Pasquier & Farrand, 1991; Stresemann, 1975).

The 16<sup>th</sup> century saw the publication of three major illustrated ornithological works in Europe, the production of which was facilitated by two innovations: the establishment of the universities in major European cities, which served as centers of intellectual activity, and the improvement in dissemination of information by relatively inexpensive books illustrated by woodcuts. The first of these works was Belon's *L'histoire de la nature des oiseaux, avec leurs descriptions & Naïfs portraits retirez du Naturel*, published in Paris in 1555; the first book ever to commission ornithological drawings, and motivated by Belon's interest in comparative anatomy and taxonomy (Pasquier & Farrand, 1973; Stresemann, 1975). The second was Gesner's enormously popular *Qui est de avium natura* (Zurich, 1555); followed by the extensively illustrated *Ornithologiae hoc est de avibus historiae libri XII* by Aldrovandi (Bologna, 1599-1603). All three works collectively represent the high water mark of ornithology and ornithological illustration in the Renaissance, and are notable not only for faithful renditions of the birds depicted, but for the inclusion of drawings of embryological and developmental details as an aid to understanding. Thus bird illustration was employed here for the first time in the intentional development of scientific understanding, as well as in the transmission of information.

The works of Belon, Gesner, and Aldrovandi dealt largely with birds native to Europe, including descriptions of exotic non-European species when these were available (Pasquier & Farrand, 1973; Stresemann, 1975). A feature of the following century was the extensive

knowledge of new species that was to inundate Europe when the age of the ‘scientist as explorer’ began. The 17<sup>th</sup> through the 19<sup>th</sup> centuries was a period of geographical exploration for ornithologists, facilitated by the frequent inclusion of an artist-naturalist on expeditions aimed at developing new trade routes, or simply voyages of exploration financed by countries looking to enhance prestige. Georg Marcgraf explored Brazil during three separate expeditions (from 1638-43) sent out under the auspices of the Dutch East Indies Company; Catesby, and later Abbott studied the avifauna of the eastern United States; John William Lewin recorded the birds of Australia (then New Holland); Levaillant explored South Africa; and Napoleon sent naturalists to Egypt and Syria (Farber, 1997; Feduccia, 1985; Jackson, 1994; Skipwith 1979; Stresemann, 1975; Whitehead, 1976). Extensive expeditions left from Britain throughout the nineteenth century; in the early twentieth century the American Museum of Natural History sent Fuertes on many expeditions, and various North American universities allowed George Sutton to continue the tradition of exploration, collecting, and painting in the field in Mexico, Iceland, and the Arctic (Chapman 1908; Drahos, 1968; Sutton, 1980; Teale, 1943; see also Sutton 1934, 1951; 1961, 1971, 1972, 1975). Contemporary American bird painters continue to explore, collect, and depict the birds of Central and South America, and NOAA voyages to the Arctic and Antarctic frequently include an artist-naturalist (Hunt, 2003g).

As taxonomy matured following the work of Willughby and Ray in the mid-17<sup>th</sup> century, and the adoption of Linnaeus’ system of classification after the publication of *Systema Natura* (1735-1758), natural historians became increasingly concerned with accurate description, detail, and evidence (Ford, 1993). French painters produced many of the best examples of 18th century bird art: Martinet, Reinhold, and Barraband, in particular (Jackson, 1994). These painters illustrated many volumes of works by Brisson, Buffon, Bonnaterre, and Levaillant; works that

for the most part were motivated by scientific dissent over taxonomic issues (Farber, 1997; Ford, 1993; Stresemann, 1975).

The greatest age of bird art - the late 19<sup>th</sup> century - essentially occurred as a cumulative result of the many specimens that were collected on these and other expeditions, providing a massive collection of material from which bird artists could work, particularly in England (Pasquier & Farrand, 1991; Smith, 1962). A considerable number of private menageries existed in the second half of the 19<sup>th</sup> century, the park of the Zoological Society of London provided access to many birds, and the collection of the British Museum included every known specimen of that time. The availability of museum specimens eliminated guesswork and inaccuracies with respect to morphology and field markings. Opportunities to work from live specimens additionally increased both realism and the aesthetic interest of the work, as the character of the bird was portrayed along with its distinguishing morphological characteristics (Farber, 1997; Skipwith, 1979; Smith, 1962; see also Dixon, 1989; Halliday, 1991; Jackson 1991; Keulemans and Caldeway, 1982; Lambourne, 1987).

A movement in natural history that had considerable implications for ornithological illustration was the gradual move from the consideration of a 'bird as specimen' to that of 'bird as integral part of the environment', i.e., a move away from taxonomy toward a more ecologically centered ornithology (Pasquier & Farrand, 1991). This concern was first demonstrated by John William Lewin, who always included characteristic vegetation, carefully drawn and to scale with respect to the birds (Jones, 1953; Wheeler & Thompson, 1996). At the same time, Catesby was adding visual behavioral notes to his paintings of the North American birds; all of his subjects are depicted feeding, calling, stretching a wing, or interacting (Feduccia, 1985; Frick & Stearn, 1961). Abbott's later work included landscape elements (Pasquier &

Farrand, 1991; Simpson, 1993), and British bird art after Prideaux John Selby insistently included habitat, which was given as much attention as the bird subject (Jackson, 1985; 1992). In America, Audubon insisted the bird be known from its natural habitat, and although he did not always paint the dramatic backgrounds for which he is known personally, his London publisher Robert Havell added these to the plates where they were not included in the original painting (Blaugrund & Stebbins, 1993).

In the twentieth century, a division arose between “environmental painters” such as Liljefors, Jacques, Thayer, and Clem, and those painters employed to illustrate bird guides for the scientific and lay communities (Pasquier & Farrand 1991; see also Hill, 1987; Jacques, 1983; Swanson, 1994; White, 1951). Publishers of modern American field guides have been inclined to omit backgrounds for reasons of economy, but some leading painters of the present day are beginning to concern themselves with depicting the ecological aspects of a bird’s existence in their original paintings (Eckelberry, 1963; Hunt, 2003a - 2003g), although landscape elements still rarely appear in field plates.

The increasing specialization of science affected bird illustration in the late 19<sup>th</sup> century, forced the ‘complete naturalists’ who had historically concerned themselves intermittently with bird study to narrow their focus and to metamorphose into ornithological specialists, and in bird illustration there has concomitantly been a movement back toward the depiction of “bird as specimen”, particularly in field guides (Farber, 1997; Pasquier & Farrand, 1991). The emergence of scientific societies and the publication of specialized journals that resulted have both increased opportunities for bird artist while ultimately limiting their artistic expression, by emphasizing didactic element of bird illustration at the expense of the aesthetic and symbolic aspects of bird painting (Devlin & Naismith 1994; Eckelberry, 1963; Pasquier & Farrand, 1991).

A few painters, notably Louis Agassiz Fuertes at the turn of the 20<sup>th</sup> century, have achieved a synthesis of styles (Chapman, 1937; Marcham 1963, 1971). Liljefors, Jacques, and Clem remained primarily painters of environments that necessarily included birds (Hill, 1987; Jacques, 1973; Pasquier & Farrand, 1991; White, 1951). In the first half of the 20<sup>th</sup> century, some painters – of which George Lodge is a fine example – adopted an either/or approach, working in the environmental tradition and also as a purely didactic museum artist (Savory, 1986). Among contemporary painters, there is a discernable correlation between the maturity of the artist and his or her inclination to move from a didactic style toward an environmental approach or at least, a synthetic compromise. Roger Tory Peterson – who set the tone of modern didactic bird painting with his introduction of the layman’s field guides – became more painterly in his later years (Devlin & Naismith, 1977). Larry McQueen has announced his intention to do this quite overtly (Hunt, 2003g), and John O’Neill is showing inclinations in the environmental and symbolic direction, at least in his non-academic work (Hunt 2003d). McClintock (1994) comments that nature writers such as Aldo Leopold, Joseph Wood Krutch, Edward Abbey, Annie Dillard, and Gary Snyder have integrated Thoreauvian Romanticism and twentieth century biology into their work. The most recent wave of bird artists - such as James Coe, Bill Strausberger, and Sophie Webb - are similarly bringing this integration into painting (Hunt 2003b, 2003c, 2003f). Such artists are incorporating exacting technical portrayals of species into a symbolic use of birds as a motif for conservation values, and in particular the intrinsic value and meaning of unmolested and unexploited landscape. This movement is in a relative infancy, but is gathering momentum in 21<sup>st</sup> century bird illustration (Hunt, 2003b; 2003c; 2003f, 2003g; Pasquier and Farrand, 1991).

## Should Natural History Illustration Be Considered Art or Science?

Illustration may be considered a subspecialty under the general art of the discipline of 'Art'. However, one question frequently asked with reference to scientific illustration, particularly those depicting natural history subjects, is "Is this Art or Science?" In an article on botanical illustration, Maura Flannery (1995) maintains that a good scientific illustration can serve two masters (art and science) simultaneously, and such a question is predicated on the false assumption that fulfilling the function of beauty and inspiration, while also transmitting scientific information is not possible. Decades earlier, Wilfred Blunt (1950) argued that meeting the requirements of both disciplines is exactly what the natural history illustrator is required to do: the successful aesthetic portrayal of an organism reveals its essence, focuses attention on the fine details that make it distinctive, and suggest that it is worthy of further contemplation or investigation. This goal presupposes some scientific intent on the part of the illustrator/artist: an intent that is not necessarily present. For example, Georgia O'Keefe, an accomplished botanical artist whose work did not attempt to convey scientific information, took a rather mystical view of the organisms she painted: "Nobody sees a flower ...really' (Foshay, 1990, p.24). O'Keefe, like many non-scientific creators of natural history images, tried to "give form to unexplainable things in nature that me feel the world is big far beyond my understanding (Foshay, 1990, p.24).

Those natural history illustrations that do aim to include scientific information concerning the organism(s) portrayed transmit appropriate and accurate information to the curious and may serve to develop better-informed questions, provide or suggest answers, and/or contribute to the development of theory. A purely scientific illustration attempts to reveal the processes and structure beneath the immediately available surface of the organism. Yet this may also serve some of the aims of the 'pure' artist for looking into an organism may leave the viewer

more curious about other species and groups of organisms; how they are constructed, and what lies beneath the surface of their existence (Flannery, 1995).

#### Potential Scientific Functions of Natural History Illustrations

Robin (1992) states that scientific images may serve six different functions to varying degrees. They may record observations, record thoughts and reflections upon observations by what they choose to emphasize (see also Tufte, 1990), demonstrate or imply cause and effect mechanisms in ecological and behavioral narratives, illustrate natural phenomena such as predator-prey interactions, give concrete expression to such concepts as mimicry or camouflage, and lead the viewer toward generation of specific insights or concepts.

Any combination of the following results may also be accomplished by effective natural history illustrations (Robin, 1992). These may demonstrate and justify taxonomic categories, by emphasizing the features upon which such categories are based. They may show links between several species or groups, or demonstrate connections between morphology, habitat, and behavior. Such links may lead inductively to generalizations about ecological relationships, the identification of new concepts (e.g., intra-specific competition), which in turn may be placed within a wider theoretical framework (such as fitness and natural selection). From an entirely different perspective, natural history illustration also demonstrates the interplay between science, art, and culture – such as the exotic bird portraits popular in 18<sup>th</sup> century France, reflecting the discovery of new sea routes and pride in a strong empire (Pasquier & Farrand, 1991), or the religious stranglehold of the Middle Ages, where animal images were only permitted as symbols in religious and allegorical scenes (Yapp, 1981). Images can demonstrate both the role of science within a culture and the personal preoccupations and dispositions of the illustrator. For example, Abbott Thayer's exhibition at the 1986 meeting of the American Ornithological Union, intended



to illustrate his “Theory of Concealing Coloration”, provoked debates and arguments about the role of plumage as camouflage that needed decades to resolve by the ornithological community (Pasquier & Farrand, 1991).

For purposes of this study, it is appropriate to interpret how Robin’s (1992) categorization of what scientific illustration can accomplish specifically applies to natural history imagery. Robin’s first category of scientific illustration is that of descriptive painting, and many natural history illustrations fit into this category. However, rendering an organism accurately and informatively requires much content knowledge (Tufte, 1983; 1990; 1997) and the sophisticated recording of thoughtful and faithful observations transmits to the viewer what the artist has learned about the organism.

A fine descriptive painting functions as a clear and knowledgeable explanation of the organism or phenomenon depicted, bringing order and clarity to the field or laboratory experience of viewing a specimen. Such paintings may also function inductively, by the generation of ‘How?’ and ‘Why?’ questions, the answers to which demand the construction of explanations using a variety of concepts. Field guide plates function inductively as well as descriptively, revising and extending ideas of the particular species by displaying a number of different views of the organism, from different angles, at different stages of maturity, and engaged in a variety of behaviors. ‘Why’ and ‘How’ questions are thus provoked but not answered by such illustrations, forcing reasoning from the particular to the general. An example of a more decorative painting that functions inductively is Audubon’s famous and fanciful painting of Northern Mockingbirds, showing the parent birds defending their nest from a rattlesnake, raising the question of ‘why’ the parents are putting themselves at risk in this way. The explanation to be inductively arrived at is biological fitness, utilizing the concept of

energetic investment in reproduction en route. Since rattlesnakes are not known to climb trees, a ‘visual lie’ (Tufte, 1983) is evoked by this painting, and the rather unlikely scene is best considered a visual confection (Tufte, 1997). However, Robin (1992) makes the point that an image does not need to be entirely correct to be instructive.

A scientific image may also function methodologically, demonstrating cause and effect (Robin, 1992). This third function of natural history images is best observed in narrative paintings rather than technical illustrations or field-guide plates, where ecomorphological relationships are depicted, and connections between diet, morphology, and habitat are established. Examples within ornithological painting might be John Gould’s plates of hummingbirds feeding (Gould, 1887), Audubon’s Red-headed Woodpecker picking grubs from the bark (Audubon, 1840-44), and numerous plates of wide-gaped flycatchers and nighthawks in pursuit of flying insects (e.g., J. Fenwick Lansdowne’s watercolor of the Common Nighthawk in Lansdowne, 1968). Gould and Richter’s plate ‘Atlantic Puffins’ (Gould, 1873) functions descriptively, inductively, and methodologically. An adult puffin is shown feeding a downy chick, barely emerged from a burrow, where this species nests to protect their young from predators, such as the Peregrine Falcon depicted patrolling the cliffs in the background. Morphological details of the foreground subjects are shown in exacting and correct detail, while the background and landscape tells an ecological and behavioral ‘story’ of the species.

Robin’s fourth category of scientific image is one that shows a self-illustrating phenomenon. This category is exemplified within ornithological illustration by paintings depicting such events as intra-specific competition (e.g., Mitford’s Northern Lapwings fighting over a snail, in Selby, 1821) or phenomena such as cryptic coloration, illustrated by coastal scenes including shorebirds (e.g., Lars Jonsson’s Curlew Sandpipers, in Jonsson, 1983). Again,

such paintings invite, and almost force, the construction of explanations about the phenomenon by the viewer, by raising the question of ‘What?’ is occurring in the scene.

The fifth category of scientific image described by Robin (1992) is that of classification, where images of organisms are fitted into a consistent schema organized by similarities and differences. Many field guides to birds intended for the layperson address this function admirably, organizing their plates by a generalized silhouette of the organism, then introducing increasingly fine distinctions within the actual plates (e.g., Coe, 2001; National Geographic Society, 2002; Peterson, 1980; Sibley, 2000; Zim et al., 1990). Wildflower guides for the layperson frequently organize their plates by petal color or fruit type, irrespective of the family or genus of the species, then subdivide these broader categories by more specific groupings, such as overall plant habit or flower shape, thus utilizing a sensory rather than taxonomic classification scheme (e.g. National Audubon Society, 1979; Peterson & McKenny, 1968; Taylor, 2002). One field guide to fungi initially classifies specimens by a pictorial key of their overall form as visible to the naked eye (Kibby, 1992), while another guide to ‘Scats and Tracks’ uses size as the initial category of classification, actually providing a paper ruler on the cover of the guide (Halfpenny, 2001).

The sixth and last potential function of a scientific illustration listed by Robin (1992) is that of conceptualization. An image that conceptualizes allows the viewer new insights, when he looks deeply into the illustration and is forced to ask, “What is going on?” and “How did this come to be?” In ornithological illustration and other images of natural history, conceptualization is the province of narrative painting, rather than field guide plates. The painting of Atlantic Puffins by Gould and Richter (Gould, 1873) described previously is an excellent example of a narrative plate packed with conceptual information for the engaged viewer. Parental behavior,

flying and hunting behavior, predator-prey relationships, and both inter-specific and intraspecific competition may be inferred from the scene. Francis Lee Jacques' evocative "Snow Geese", showing several hundred birds in flight across a flat marsh (without a single misplaced wing among them), stirs questions about migration and the relative advantages and disadvantages of flock behavior rather than solitary habits (see Pasquier & Farrand, 1991, p.213 for image; also Jacques, 1973).

To summarize, natural history images fulfill a number of possible educational and cognitive functions as they engage the viewer aesthetically. They may describe and explain an organism or phenomenon, demonstrate cause and effect relationships, provoke inductive reasoning about the subject matter, teach visual classification skills by example, and promote the development of explanations, and force the utilization of previously learned concepts in turn. The extent to which an illustration is useful in any of the former respects is dependent upon the visual literacy of the viewer (discussed later in this review), and also upon the design quality of the graphic or the painting. Where Robin discusses and dissects the potential power of the scientific image, Edward Tufte (1983; 1990; 1997) is concerned with the design strategies that maximize information representation in the image, and facilitate the meaningful transfer of that information to the viewer.

### Design Ideals in Ornithological and Other Natural History Illustration

#### Elucidating Standards of Excellence in Science Graphics: Edward Tufte's Graphic Design Theory

Within Tufte's schema of design, a scientific illustration is conceived as a 'data map' of the organism or phenomenon depicted (Tufte, 1983; 1990; 1997), and his design theory for the effective display of such data rests upon two major axioms. First, the maximum possible

information about the subject is to be communicated as efficiently as possible, that is , “the larger the share of the graphic’s ink devoted to data, the better...Maximize the data-ink ratio, within reason” (Tufte, 1983, p.96). Second, graphics should be ‘relational’, explicitly showing relationships between variables or components of the illustration wherever possible. Relational images link two variables and encourage the viewer to assess possible causal relationships.

Within the area of natural history illustration, well-designed field guide plates are frequently packed with information, thus exemplifying the maximum data-ink principle, while narrative paintings offer more relational possibilities. Tufte (1983) found that only 42% of science graphics overall might be considered relational in nature, but modern ornithological illustration considerably exceeds this estimate. For example, a painting of a rainforest scene that contrasts species typically occupying the understory to those found in the canopy has a number of relational possibilities in terms of ecological, behavioral, and morphological variables, as does a painting of a mixed species group of shorebirds, showing the zones where they are typically found feeding. A relational illustration sometimes found in field guides is a map with regional differences in morphology for a given species, thus linking intra-specific variation with geographic variables.

Satisfying both of Tufte’s axioms may present a conflict for the natural history illustrator, for the two objectives are not always easily reconciled. The influential ornithological illustrator Louis Agassiz Fuertes was forced to seek this reconciliation in the early stages of his career, while he was under the influences of three powerful mentors. Elliot Coues, founder of the American Ornithological Union and the foremost American ornithologist of the late 19<sup>th</sup> century, instructed Fuertes to concentrate on data (the bird) and eschew contextual accessories such as scenery and habitat details (Peck, 1982). Simultaneously, Frank Chapman, curator of birds at the

American Museum of Natural History and editor of *Bird-Lore* (later to become *Audubon* magazine), wanted more environmental features in the commissions he awarded to the artist (Chapman, 1937; Pasquier & Farrand, 1991) Fuertes' artistic mentor, painter Abbott Thayer, was unconcerned with either objective, and urged his pupil to see and paint in terms of values given to local colors by light. It is a measure of Fuertes' talent and flexibility that he managed to incorporate these apparently conflicting directives into data-rich and accurate species profiles that provide rich context without gratuitous decoration (see Pasquier & Farrand, 1991; Peck, 1982; Sutton, 1979).

Tufte's standard of excellence in data graphics, which applies to ornithological and other natural history illustration, can be described by the following five-point rubric (Tufte, 1983):

1. The illustration should function as a well-designed presentation of interesting data.
2. The illustration should be relational, communicating complex ideas with clarity, precision, and understanding
3. The illustration should maximize the use of data-ink, that is, communicate the greatest amount of information or number of ideas with the least ink in the smallest possible space.
4. The illustration should be multivariate, communicating as many different variables or dimensions of the subject matter as possible.
5. The illustration must communicate a truthful picture of the subject.

#### Achieving Integrity in Scientific Illustration

Tufte (1983) emphasizes, and devotes a great deal of ink, to his fifth point – the importance of integrity in graphics. Graphical integrity implies that the designer or artist aims to achieve more than showing “the obvious to the ignorant” (p. 53), and explores the complexity of

the subject depicted to the fullest possible degree. Integrating explanatory text with graphics, and clear, detailed, and thorough labeling on the illustration itself also function in achieving integrity, by eliminating visual guesswork on the part of the viewer.

The careful elimination of visual deception, intentional or otherwise, is also critical to graphical integrity (Tufte, 1983). Deception of the viewer may occur if parts of a graphic generate expectations about other parts. In the context of natural history illustration, this implies that details of landscape, characteristic vegetation, the presence of possible predators or prey items etc, need to be both qualitatively correct and in the correct proportions, to avoid evoking a ‘visual lie.’ The latter point is important since visual drifts in scale have magnifying effects upon the expectations and perceptions of the viewer. Such distortions of scale may be encountered in some field guides, where mixed species plates - such as those of shorebirds – do not have the relative size of the species clearly indicated, even though field markings of each species are depicted correctly, and notes upon the actual size of the bird may be included somewhere in accompanying text. If the size of such species is not clearly indicated on the actual illustration, visual integrity is nonetheless lost.

Inferior illustrations – such as those with inexact morphometric representation – encourage distortions of perception in the viewer. Tufte (1983) refers to the ratio of the size of the effect suggested in an illustration to the size of the actual effect in the subject or phenomenon, as the ‘Lie Factor’ (p.57), which should ideally be equal to one. These ‘Lie Factors’ are liable to occur in field guide illustrations, where the field markings of an organism that are emphasized in the illustrations are not always perceived to that extent in the field. For example, the Ruby-crowned Kinglet, a small and somewhat drab olive bird, is generally depicted in field guides with emphasis upon the bright orange-red crown feathers (e.g., Coe, 2001, p.118;

National Geographic Society, 2002, p.339; Peterson, 1980, p.217). In the field, these crown feathers are frequently hidden unless the bird is actively displaying.

The optical plane in which the subject is depicted may also evoke a visual lie by generating perceptual expectations in the viewer that may not be met in the field (Tufte, 1983). The Cedar Waxwing is characteristically portrayed in side-profile (e.g., Coe, 2001, p.117; National Geographic, 2002, p.364; Peterson, 1980, p.225) whereas in the field, this species is generally sighted from below, as they feed in flocks around the tops of small fruit trees. Likewise, many fine illustrations of different species of hawk distinguish these birds by the barring patterns on their tail feathers (e.g., Coe, 2001, p. 16 and pp. 49-51; National Geographic, 2002, pp.112-119. ; Peterson, 1980, pp. 165-171 ; Sibley, 2000, pp.114-25), a detail rarely observed in the field since such species are generally observed from a considerable distance: in flight or perched upon some tall structure. Although many of these field guide artists have painted these birds in ventral view, as they fly overhead, the detailed features depicted are only useful in identification when observing a specimen in a museum or laboratory situation. Fluid drawings of hawk silhouettes while in flight, or of their characteristic postures when perched in trees, such as those offered in *Hawks in Flight* (Dunne, Sibley, & Sutton, 1988), are of greater utility in the field.

Thus if not deliberately lacking in integrity, many field guide illustrations – although they may be technically accurate – are actually of limited value to the novice birder in the field. The preceding examples offer subtle demonstrations of Tufte’s ‘Lie Factor’ at work in natural history illustration, where the emphasis of the effect illustrated may not be perceived in reality. This is not to imply that field guide illustrators are incompetent or dishonest, simply that meeting Tufte’s exacting standards on all levels is extremely difficult, may not coincide with the intent of



the illustration or publication, and frequently requires some realistic compromises. For example, ‘visual lies’ or the misrepresentation of perspective are endemic in full-landscape portraits of birds, by strict Tuftean standards. In the majority of such paintings, the viewer sees a bird displaying itself against a background of characteristic plant material, where a strictly truthful representation would show a flash of a tail feather or a wing bar from within the foliage. In truth, birds do not position themselves against foliage waiting to be observed in canonical view, but painting ‘truthfully’ in such instances would be at the expense of considerable information.

### Maintaining Scientific Integrity in Narrative Ornithological Painting

Like Elliot Coues, Tufte is generally against the inclusion of decorative aspects in scientific graphics, referring to such as the “the sign of a hack at work” (Tufte, 1983, p. 59). However, the inclusion of relevant decorative details may be justified in ornithological and other natural history illustrations. The bird - or other organism - does not exist in isolation from its environment but is rather an intrinsic part of it, thus appropriate landscape elements, including food items of the species, actually add information to the graphic and direct the viewer’s attention to ecological aspects of the bird. A related Tufte principle concerning information design states that the number of information carrying dimensions depicted should not exceed the number of dimensions in the data, lest viewer perception is led astray (Tufte, 1983). Thus, if a background element is not relevant to identifying or understanding the bird, it becomes ‘chartjunk’ (Tufte, 1983, p.107) and should be eliminated.

Field guide plates do not generally err in this respect, and where excess material is present in narrative ornithological painting, this frequently serves a purpose in directing the viewers’ attention to a relevant detail, or as an ‘aesthetic hook.’ It is sometimes desirable to include some apparently extraneous material in portrayal of the ‘jizz’, or the essential character

of the bird, particularly a rare or exotic species, or one not easily observed in its natural surroundings due to reclusive behavior. Thus a decorative aspect to a bird painting does not preclude the presence of valuable scientific information in the work.

Gratuitous details, especially those taking the form of inaccuracies in background, are sometimes seen in older narrative paintings. Fantastic rock formations and an out of proportion narwhale are shown as a background for a mixed seabird plate by the 18<sup>th</sup> century painter Francois Nicholas Martinet, and included in the ornithological volume of the Comte de Buffon's *Histoire Naturelle* (in Salerne, 1767). An otherwise competent painting of Garnet Pittas (*Pitta granatina*) by John Gould and William Hart shows these ground-dwelling birds of Old World tropical forests in an open rocky clearing harassing an owl (in Gould, 1969). The lavish romantic landscapes against which Martin Johnson Heade painted South American hummingbirds, are gratuitous in the sense that these very fine Brazilian landscapes do not necessarily reflect the habitat of the particular species showcased in the painting (Stebbins, 2000). Martinet, and also Gould and Hart, were simply working from imported bird specimens about which they had very limited information, where Heade was willing to sacrifice ecological truth to aesthetics and romantic ideals (Pasquier & Farrand, 1991).

Where landscape details are appropriate, to function informatively and to exceed the role of decoration, such details must be represented correctly, for they too are 'data points' on the map. Accuracy in botanical and landscape details was a problem in ornithological and other natural history illustration in the past, when many artists worked from specimens of birds taken from environments unfamiliar to them. Conversely, many of the most informative natural history illustrations have been taken from the information and sketches in field notebooks, where the artist was intimately familiar with the habitat of the organism. Examples of such work is

found in Erasmus Darwin's detailed drawings of the fertilization process in the freshwater diecious plant *Vallisneria spiralis* (Darwin, 1791), the illustrated diary kept by Charles Darwin during the five year voyage of the HMS Beagle (Darwin, 1933), and Maria Merian's entomological studies of Surinam (Merian, 1771; Tuft, 1962). In recent ornithological illustration, George Sutton diligently sketched and painted in the field as he took species and habitat notes during travels from the Arctic through Mexico (see Sutton, 1934, 1957, 1971, 1975), Lars Jonsson records the bird life of his summer home in paintings (Jonsson, 1983), Sophie Webb has created award-winning children's books from her illustrated journals of research in Antarctica and Alaska (Hunt, 2003g; Webb, 2000; Webb. 2004), and ornithologist-artist Daniel Lane sketches consistently as a routine component of his birding activities (Hunt, 2003f).

#### Maintaining Integrity of Ornithological Illustrations in Field Guides

An illustration of a bird or other organism should provide direct answers to relevant questions about size, form, morphological and behavioral adaptations, and ecology. Graphical integrity requires that data not be quoted out of context (Tufte, 1983), thus to keep these 'answers' within proper context, the background of the subject should only include elements relevant to the ecology of the organism, with those elements rendered in proper perspective. Mixed species plates should adhere to the principle of proper context by indicating how the organisms are related, by taxonomy or by habitat. Modern illustrations in technical guides generally do organize their species according to a strict taxonomic arrangement (e.g., Kaufmann, 1990; King et al., 1975), while some field guides intended for the beginner, and many narrative paintings show organisms related by niche or habitat (e.g., Coe, 2001; Lansdowne, 1968; Matthiesson, 1967).

The visual control of context is another aspect of this principle (Tufte, 1983). For example, the comparison of a one species with another is appropriate, but the reasons for this comparison should be explicit and strictly adhered to, i.e., the viewer should be made aware of the aspects of the comparison. Examples of comparisons made within an appropriate context might be comparing typical family characteristics, highlighting differences and similarities within members of a genus or family, or comparing the plumages of birds that appear similar at first glance, as is done to good effect in Peterson's *A Field Guide to Warblers of North America* (Dunn et al., 1997). Here the comparative plates highlight subtle species differences in fall and winter plumages between birds that are easily distinguishable in their breeding plumages.

#### Tufte's Principles of Integrity in Illustration: A Summary

To reiterate, illustrations of high integrity enhance the information content and educational potential of the image, and this is especially so when the magnitude and direction of differences and contrasts are made apparent (Tufte, 1983). Five principles of integrity to be examined when judging a scientific image are:

1. Magnitude should be represented with attention to proper proportion.
2. Illustrations should be supported by text, preferably as clear, thorough, and detailed labeling on the actual graphic.
3. Variation in the data or subject only should be shown, and decoration or design variation should be avoided
4. Variables depicted should be restricted to those relevant to the subject.
5. The image should be shown in proper context.

### Meeting Tuftean Criteria: Sources of Natural History Illustrations with Integrity and Sophistication

A scientific illustration of integrity and sophistication requires finely tuned judgment about the content, requiring that the artist not only be trained in the visual arts, but also has a thorough knowledge of his subject (Tufte, 1983). A lack of biological knowledge has sometimes been true of bird painting of the past, but is rarely the case with modern ornithological illustrations. Ornithological illustrations produced since the early 19<sup>th</sup> century are increasingly the work of artists who know birds and ornithology well, both from a personal and an academic perspective (see Chapman, 1937; Derry, 1985; Devlin & Naismith, 1977; Hill, 1987; Pasquier & Farrand, 1993; Smith, 1962; Sutton 1980; Van Gelder, 1982). Since the rise of birding as a serious avocational pursuit, even those bird artists who are not professional ornithologists have frequently been avid bird watchers since childhood, and have amassed a great deal of lay experience with their subject (e.g., Hunt 2003c; 2003g; 2003h). A commitment to scientific truth and accuracy has developed with their increasing knowledge and interest. Tufte's complaint that graphic artists have a tendency to animate and exaggerate subject matter to the detriment of information content and accuracy (Tufte, 1983) is belied by an examination of modern field guides, particularly those intended for the advanced novice (e.g., Coe, 2001; Dunn et al., 1997, Dunne et al., 1998; Kaufmann, 1990; King et al., 1975; Howell & Webb, 1995).

### Design Solutions for the Two-Dimensional Representation of a Multivariate Reality

The second volume of work outlining Edward Tufte's theory of graphic design for scientific illustration (Tufte, 1990) is entirely devoted to the problem of escaping 'flatland' when attempting to portray a multivariate world on a plane surface. A variety of strategies are discussed that sharpen the information resolution of illustrations by increasing the number of

dimensions of information that can be represented on a dimensional surface, and also the information delivered with respect to the area employed to do so.

Conventional perspective drawing, developed in 15<sup>th</sup> century Italy, enriched the representation of everyday objects, and this technique is competently executed in both didactic and decorative works of ornithological illustration. Tufte (1990) suggests that three-dimensional sciences can also deliver a three dimensional image by way of two paired images that are then mentally fused by the viewer. However, this stereo illustration technique is rarely if ever employed in ornithological or other areas of natural history illustration, as in another Tufte solution – that of the symbolic encoding of images, commonly seen in dance notation and fine cartography.

#### Adding the Dimension of Time to Illustrations

Time series also aid the envisioning of information about an organism or phenomenon, and increase data density by incorporation of the additional dimension of time into an illustration, and this technique is commonly encountered within the field of natural history illustration. Series of illustrations showing the field marks of an organism as they vary with age or season are frequently found in both lay and technical natural history guides, as are life-cycle diagrams. Tufte claims that a well-designed time series of this nature may increase the data density of an illustration tenfold.

Small multiples of the same organism or phenomenon, in which only one variable changes between the images, contribute to economy and efficiency of perception, as the viewer can decode and comprehend the information for one aspect of the data, while simultaneously accessing the data in all the other ‘slices’ (Tufte, 1990). As the eye moves from one image to the next, this constancy of design allows viewers to focus upon changes in information rather than in

changes in composition or in graphical design. Small multiples are utilized for species comparison in both field guide and technical illustrations. Narrative works may also depict multiple individuals of the same species. However, in many of these works, more than one variable (such as behavior, gender, posture, and stage of maturity) changes between multiples, thus lessening their power to enforce differences in terms of Tufte's theory. For example, birds indexed by intraspecific variation may be depicted exhibiting different behaviors, e.g., feeding in one small multiple, preening or calling in the next. Also, pairs of a species that exhibits sexual dimorphism may be shown in different planes. Thus, in natural history illustration, the technique of indexing by a single variable is susceptible to being broadened (or diluted in Tuftean terms), and visual comparisons tend to be invited rather than enforced.

#### Enhancing Density and Complexity of Information

Other methods recommended by Tufte (1990) for enhancing the density, complexity, and dimensionality of information include: micro/macro readings of detail and panorama, the layering and separation of data, multiplication of images, the use of color to indicate hierarchy of importance, and narratives of space and time. Tufte cautions that for all design solutions, the design strategy itself should be transparent and self-effacing, and avoid distractions from the data itself by graphic apparatus ('chart junk') or unnecessary ornament. The diversion of dramatic design strategies and decoration corrupts illustration by adding content-empty dimensions to the data, and deflecting attention from the actual information contained within the image.

#### The Simultaneous Depiction of Detail and Panorama via Micro/Macro Readings

Tufte's (1990) concept of micro-macro readings concerns reading detail that culminates in large extended structures. Achieving this requires an unconventional design strategy that utilizes the multi-layering of information to clarify by adding detail. In ornithological illustration, such

conceptual multi-layering of detail is exemplified by a carefully rendered group of birds of one species, exhibiting different characteristic postures and behaviors, and shown against a full and detailed background characteristic of that species, including details of vegetation in the foreground, and an overall indication of landscape form and features in the distant background. Micro/macro readings of this nature are more the province of narrative painting than field guides in ornithological illustration. Many painters of birds in full landscapes have utilized this approach, from the early Chinese painters through present day painters such as H. Douglas Pratt and Bill Strausberger. Works where this strategy has been adopted fully include Audubon's *Long-billed Curlew* (in Audubon, 1838), Gould's *Ground Jays* (in Gould, 1969), Wolf and Richter's *Great Bustards* (in Gould, 1873) Allan Brooks' *Little Blue Herons* (in Forbush, 1973), and William T. Cooper's *Antipodes Green Parrot* (in Forshaw, 1989) and *Carmine Bee-eaters* (in Forshaw, 1983).

When painted and composed in a manner that leads the eye from relevant details of the organism, through a comparison of organisms, and then to the habitat occupied by the species, such artwork is very effective in the delivery of information. The details are given the most visual emphasis by visually ordering the sequence in which the eye and the mind encounter the information (Tufte, 1990). Such emphasis is achieved instrumentally by varying line weight and gradations of color in a complex and subtle fashion. Certain ornithological illustrators – Terence James Bond, James Coe, Daniel Lane, and Richard Weatherley to name a few - are highly skilled at contributing to the viewer's visual/cognitive map in this fashion. This ability must be especially well-developed in those painters who work primarily with more cryptic species (such as the wrens and thrushes) rather than more colorful and/or tropical birds.



### Improving Comprehension of Information by Visual Layering and Separation: The Contributions of Color, Line, and Compositional Approach

Tufte (1990) describes “confusion and clutter...as the failures of design” (p.53), impeding the comprehension of information. The technique of layering and separation is recommended for the reduction of noise and enriching the content of images. The layering and separation of visual information may also be achieved by the use of color (where saturated colors in small quantities indicate layers or hierarchies of information) and indicated by expressive and gestural lines. The use of line and color combine to make strong statements about the relative importance of particular details (Tufte, 1990). This is a difficult design strategy to employ in paintings of organisms, which are necessarily representational and offer little opportunity for the use of the symbolic. Nonetheless, some painters have employed a variant of layering in their use of color, where the bird itself is rendered in saturated colors, the surrounding vegetation and rocks etc. in less saturated hues, and the far background or landscape is rendered in a pale wash. Thus the eye is first drawn to the bird, then takes in the characteristics of the immediate habitat of the organism, and finally places the species in the context of a larger ecosystem. Louis Agassiz Fuertes was a master of subtlety in this use of color for layering and separation (see Peck, 1982, Sutton, 1989), and his pupil George Miksch Sutton also used color layering extensively, especially in his illustrations for *High Arctic* (1971), where the pale and subtle colors of the subject matter particularly suited this approach. Continuing the Fuertes’ tradition, Sutton’s own advisees Don Eckelberry and John O’Neill also employed color to emphasize details and indicate hierarchies of relative importance (see Eckelberry illustrations in Brown & Amadon, 1968; O’Neill plates in O’Neill, 1999).

Other equally distinguished ornithological painters have eschewed color as a means of layering information. Swiss impressionist Leo Paul Robert indicated differences by means of

variation in texture, utilizing many very thin layers of paint to achieve the desired effect. Al Gilbert uses bold pattern and rich colors throughout his paintings of tropical forest birds, relying on compositional techniques for emphasis. However, such techniques are those of the maverick, and the majority of bird painters and illustrators do rely upon the use of color and/or line to structure visual information.

Variation of line quality is generally seen in ornithological illustration in technical guides for the specialist, or when feather texture is an important characteristic of a species. In such cases, different feather types are shown with more distinct lines, different lines, and are painted in relatively greater detail. Historically, many of the great bird portraitists have relied upon the skillful use of line for various degrees of emphasis. The animation and strong graphic qualities of the plates of John William Lewin's *A Natural History of the Birds of New South Wales* results from the artist's surety of line (see selection of images in Sir William Dixon Library, 2003). In the 18<sup>th</sup> century, Jaques Barraband was a master of realism in the depiction of feathers (see Barraband illustrations in Levailant, 1963; Pasquier & Farrand, 1991). Later, Edward Lear varied line quality extensively and precisely to create a sense of meticulous detail in his bird portraits (see Lear images in Gould, 1834, 1837; Selby, 1821; Hyman, 1980) and the subjects of Joseph Wolf's extraordinary paintings for Daniel Giraud Elliot's monograph of the pheasants derive their immediacy from the firm use of bolder lines among many finer lines (see Wolf, 1988). Of the more recent bird-in-environment school, Lars Jonsson makes selective use of line, detailing the organisms but almost eliminating visible lines in his landscapes (Jonsson, 1982, 1983, 1992, 2002). Among more technical current painters, Robert Mengel is notable for finely differentiated line use in the distinctive pen and ink drawings that illustrate the five-volume

*Handbook of North American Birds* (Palmer, 1976), as does Richard Weatherley in a monograph on the Maluridae (Schodde, 1982).

The use of layering and separation by color and line is not entirely ubiquitous among bird painters. Roger Tory Peterson dispensed with such subtleties in his best selling *A Field Guide to the Birds* (1934), which has since been revised five times. Peterson chose to indicate important diagnostic characteristics with arrows, an innovation that proved immensely popular with novice bird enthusiasts. Nonetheless, as a general rule, the ornithological painter is forced to make choices about the details of the bird that he or she wishes to emphasize. Without clear and distinct decisions of this nature, an undifferentiated and unlayered image results; one which may contain all appropriate information, but fails to communicate it in an appropriately hierarchical order of importance (Tufte, 1990). In most didactic illustrations, and also many narrative works, backgrounds are sketched in lightly and colored unobtrusively, equivalent to the ‘light grids’ recommended by Tufte in representations of quantitative data (Tufte, 1983, p.116) and thus do not compete with the bird in terms of information transmitted. A background can be immensely detailed where appropriate – as in the ‘bird in environment’ school of narrative painting originating with Lars Jonsson and Bruno Liljefors – but should never be obtrusive or obscure the importance of the bird.

While a background should be subtle, Tufte (1990) also points out that the other extreme of white negative space surrounding the data of interest can also be noisy and distracting. Many bird portraitists wash the area immediately surrounding the bird in a light neutral color to eliminate this effect, and the majority of field guides follow this practice. Similarly, few birds are depicted framed by a landscape; for “a single character gains clarity and meaning by an orderly relationship of the space background that surrounds it” (p.65). Those birds that are depicted in

visually cluttered surroundings are frequently rainforest dwellers that are actually observed in dense cover, thus the painting gains in ecological realism although sacrifices some clarity. Al Gilbert (Van Gelder, 1982) and John P. O'Neill (Hunt, 2003d) are two highly regarded modern painters of rainforest and cloud forest birds who sometimes consider this compromise necessary.

In modern field guides - where a variety of bird species are depicted upon the same pages - grids, boxes, and frames are absent, and placement of the individual species is used to direct the eye (e.g., Coe, 2001; National Geographic Society, 2002; Peterson, 1980; Sibley, 2000; Zim et al., 1990). Artists struggle with the precise placement of the birds within each plate, in an attempt to direct the viewer's attention through a series of visual 'paragraphs' (see Hunt, 2003d, 2003e, 2003h). Prominent ornithologist and artist John O'Neill reports spending more time and effort on the arrangement of species within a full-page plate than he does on actually painting the birds (Hunt 2003d). Thus ornithological artists are in implicit agreement with Tufte (1983) that layering and separation of data (species) must be enforced, for information essentially consists of "distinctions that make a difference" (p.67).

#### Visual Enforcement of Comparisons to Promote Reasoning

Tufte (1983) states that the question "compared to what" (p67) is central to human reasoning. Small multiple designs, in which a design is insistently repeated with one variable changing between design units, visually enforce comparisons of changes, the differences between certain objects, and the scope of alternatives. The small multiple is frequently the best design solution where comparisons are required or desirable. Each multiple functions as a unit of information, ideally positioned within the eye-span of the viewer, so that uninterrupted visual reasoning may take place. Tufte is insistent that such visual comparisons are enforced within the scope of the eye-span. This is of fundamental importance to scientific illustration in general and

to natural history field guides in particular. In such works, the placement of subtle visual comparisons on succeeding pages is not effective, and the best editors and illustrators of bird books take this into account. Within Tufte's theory, eye movement between illustrations requiring comparisons should be minimized. Thus in ornithological field guides, the most similar birds should be shown adjacent to each other

In general, a small multiple approach to design reveals comparisons that are not easy or obvious, and thus is an ideal solution for the portrayal of bird groups such as "LBJ's" or "Little Brown Jobs" and those of some shorebirds, the identification of which is difficult for the novice. Small multiples can also be arranged in a time series (Tufte, 1990), an appropriate design in ornithological illustration where plumages change with maturity and or season.

#### Special Problems of Color Choice in the Natural History Illustration

Although the human eye can typically distinguish between 20,000 and 30,000 colors, 20-30 colors are the maximum that may be encoded for effective information processing. Tying color to information in illustration is theoretically simple: Tufte (1990) states, ironically quoting Paul Klee, that this is merely a matter of "putting the right color in the right place" (Klee, 1961, p.39). In practice, the placement of color in information graphics is a subtle and complex matter. Decisions about color placement have for the most part been made ahead of time by nature for the natural history illustrator, whose use of color is for the most part strictly representational, as he or she attempts to imitate reality. However, color may function informationally in an ornithological illustration, and also sometimes to enliven or decorate a background.

Despite the apparent ease of translating the readily available colors of nature and organisms onto paper, the choice of color is in fact fraught with difficulties for the natural history illustrator. Since ground color tends to subtract its own hue from the bird, the effects of

background details upon the main subject must be considered (Tufte, 1990). Color is a subtle and exacting tool of informational illustration, and is liable to differences in perception between viewers. Perceived shifts in color are also brought about via pattern and texture. A white area of plumage, for example, will produce a contextual color shift in adjacent areas, and contour lines – such as those outlining a wing – produce further cognitive shifts.

Master bird painter Louis Agassiz Fuertes, who was instructed by the classically trained Abbot Thayer, was well aware of the problems inherent in color choice, and wrote extensively to his pupil George Miksch Sutton on the subjects of shadow color, local color, and combinations of reflected and local color (Sutton, 1979). One letter dated 1915 charges Sutton with this exercise: “Analyze with a perfectly unbiased mind...take a piece of white paper, cut a hole in it and study your color locally by isolating it from the rest and comparing it with the white paper...Do this outdoors too, and see what surprises you get as to the actual color of hills etc. in the distance...All these things will help clear your mind of preconceived notions of color – especially it will show you that local color (by which I mean the exact color, analytically, of any given part of your whole subject, isolated from the rest) is practically never unmodified by either warm light or cool shadow; in the latter case, too it almost invariably absorbs color either reflected from nearby objects or blue absorbed from the atmosphere. You don’t have to have blue sky in the latter case. That is why your warbler looks muddy” (Sutton, 1979, pp. 29-30). Later in the same lengthy letter – for summer visits apart, Fuertes tutored the teenage Sutton by mail – Fuertes emphasized the importance of beginning a color exercise by locating the darkest part of the subject: “Usually you will find the darkest line just beyond the line – not at the edge, for some light always comes around the other way, usually as a reflection from something else...In sunlight, everything on the lighted side- black included, will prove lighter than anything

in the shaded side, white included...These are all basic principles that I may have posited before” (Sutton, 1979. pp. 31-32). Thus did Fuertes link proper rendition of color with the ability to observe carefully and truthfully. Sutton felt that Fuertes overstated the importance of correctly seeing color, and was somewhat offended by the criticism of his carefully rendered warbler as ‘muddy’, until he carried out Fuertes’ instructions, and became an immediate convert to the fundamental importance of the correct local color to the overall quality of the painting. Punching a hole with a lead pencil into a piece of white paper, Sutton examined his painting and also the skin of the Chestnut-sided Warbler that had served as his model, directing his attention to the lower belly and undertail coverts that were in the deepest shadow: “At once I realized what Fuertes had meant: insofar as those parts of my subject were concerned, the beauty had been lost...the illusion of featheriness was missing...there was no smoothness, softness, no hint of the translucence. I had put down one color and decided that it was wrong...then I had put down another color hoping to correct the first...that had not helped...’muddy’ was not a strong enough word” (Sutton, 1979, pp.33-34). Decades later, Sutton was to transmit Fuertes’ insistence of the fundamental importance of rigorous color observation and analysis to his own students – Don Eckelberry and John O’Neill in particular. Thus Thayer’s legacy of correct color perception and representation has been transmitted to modern bird painters.

Tufte (1990) agrees that color itself is ‘subtle and exacting’ (p.93), and is complicated by the complexity and uncertainty of translating even correctly perceived color onto paper. Tufte cites fine cartography as a standard of excellence in informational graphic design, observing that in classic cartographic practice, two rules of color are observed. First, placement of pure, bright, or strong colors adjacent to each other is to be avoided, on the grounds that “noise is not music” (Imhof, 1982, p72), and such extremes of color should be used sparingly on dull backgrounds. A

second axiom is that placement of light, bright colors next to each other produces optically unpleasant effects, and inhibits visual information processing.

Obviously, the painter of birds, especially brightly colored tropical species, may be allowed little discretion with respect to the adjacent placement of bright colors, and the second rule of cartography is largely irrelevant to ornithological illustration, since such colors tend not to exist in nature. Thus the ornithological illustrator faces a rather different set of challenges than do other graphic artists. In the instance of colorful tropical birds, color functions inherently as an informational label, as most such species are memorable for this very characteristic. However, recognition aside, these bright colors tend to obscure other relevant details, such as feather type or texture, presenting a further problem to the painter. Painters such as Jaques Barraband, Edward Lear, William Swainson, John O'Neill, and H.Douglas Pratt – all of whom worked with tropical species possessing brilliantly hued plumages - have circumvented this problem with the subtle use of line to emphasize details independently of color (e.g., Gould, 1834, 1837; Hyman, 1980;Levaillant, 1963; O'Neill, 2004;Pasquier et Farrand, 1991; Pratt et al., 1987; Selby, 1821).

Most species of temperate or sub-tropical birds possessing areas of bright color in their plumage have relatively small areas of such color against a more muted plumage, in which case the color serves as a highlight. The challenge for the illustrator is the representation of other features of the organism that are not highlighted in this fashion, such as how to draw attention to a buff eye-ring, or an unusual toe arrangement, in a bird possessing a scarlet crest or vivid yellow wing bars. In such cases, the use of line must once more compensate as a tool for emphasis.

Painters of more cryptically colored birds are generally forced to utilize a more neutral and subdued palette for both bird and background, where the colors are inherently coherent in terms of information quality. Such subject matter offers the opportunity of cartography, where



local emphasis of relevant or important background features can be provided via a ‘spot highlight’ of intense color. Certain past and present British bird painters are masters of this technique, particularly George Lodge (Beebe, 1922) and Terrance James Bond (Bond et Hume, 1993).

In Tuftean terms, color might be considered a visual noun (Tufte, 1990, p.81), as in ‘red tail’ or ‘yellow crown’. In dull-colored or cryptic birds, color is actually more important in naming fine distinctions of plumage, as in the “Little Brown Jobs”, where the individual feathers might span a range of hues and values as the plumage varies from buff to rufous over the body of the bird. A sensitive handling of this more neutral palette is most important in conveying plumage information in more subtly colored birds, and forms the basis of one argument for a thorough artistic training of bird artists. As Fuertes noted (Sutton, 1979) the value scale of browns and grays, for example, is particularly important for the artist to interpret perceptually as he or she views a specimen, and also in his ability to represent these values accurately. The inclusion of lines in the plumage of ‘dull’ birds is also an important interpretive aid for the less visually literate viewer, who may not be an expert perceiver and translator of color.

#### Spatial and Temporal Information in Narrative Ornithological Painting

Tufte (1990) describes a graphic functioning as a narrative of space and time as one that consists of a data map combined with a time series. In ornithological painting, the bird is a data map, and a space-time narrative in this area would be exemplified by a portrayal of a flock of birds moving over a landscape, such as in the Francis Lee Jaques paintings reproduced in Jaques (1973) and Swanson (1994). Space–time narratives are the province of the more decorative school of ornithological painting, and are rarely seen in field guides, but such depictions may yield significant biological information to the viewer. Such paintings may deliver information

about behavior of flocks, the characteristic silhouette of a given species in flight (important because field marks cannot generally be observed in birds on the wing), or deliver biogeographical and environmental data. Art work by Robert Verity Clem (see Mattiesson, 1967), Francis Lee Jaques (see Jaques, 1973; Swanson, 1994), Lars Jonsson (see Jonsson, 1982, 1983, 1992, 2002), Bruno Liljefors (see Hill, 1987), and George Miksch Sutton (see Sutton, 1971) include fine examples of bird-in-landscape painting as space-time narratives.

### Scientific Images as Visual Explanations

Tufte's third volume of work covering design strategies for effective conveyance of scientific ideas (Tufte, 1997) describes strategies that achieve Robin's (1992) methodological function: those that demonstrate cause and effect and thus force the viewer to develop a reasoned explanation for the phenomenon illustrated. Such strategies are of especial importance to this study of ornithological illustration, for whereas a well-executed bird portrait by a competent ornithologist is generally rich in description, such works tend to be weak in triggering or displaying explanation. Thus when considering the use of ornithological images in education, one should be aware of the design approaches that go beyond the display of information toward encouraging reasoning, explanation, and the use of available concepts. Tufte is emphatic that when principles of design replicate processes of thought, the resulting graphic leads to the construction of knowledge by the viewer, requiring that the designer have clear insight into his or own thought processes.

Such design requires awareness of the inherent quantitative aspects of the data or subject, an ability to relate the statistical and the visual, a commitment to avoiding disinformation or 'pictorial magic' (Tufte, 1997 pp. 55-75), and an awareness of the small differences that will alert and engage a viewer's reasoning processes. Appropriate design strategies for the

construction of explanations frequently arrange images in narrative form, and tend toward the visual and lyrical rather than the quantitative, an approach for which natural history subjects are ideally suited. Tufte is concerned that designs for displaying such subject matter conscientiously enhance the inherent richness and complexity of the subjects, delivering the same with the maximum resolution and clarity. Where such strategies are well developed and strictly adhered to, even the two-dimensional limitation of paper representation may extend the depth of the viewer's knowledge and experiences. Especially suited to such attempts at deepening knowledge with graphics are the architectures of comparison and narrative, particularly parallelism, multiple image use, and the juxtaposition of many events or phenomena in 'visual confections' (pp.121-15).

#### Quantitative Explanations as an Aspect of Ornithological Illustration

The non-specialist rarely considers birds are in terms of their quantitative attributes. Tufte (1997) makes the point that all images inherently evoke some approximant or exact assessment of quantity, as the viewer senses size, scale, and number. Ornithology involves the order of magnitude reasoning and precise measurement characteristic of all scientific work, e.g., the number of primary feathers, ratios of wing/body length, skull and bill dimensions, etc. Thus the design problem for the ornithological illustrator is one of representing such quantities, utilizing a strategy that renders the bird quantitatively eloquent. Tufte suggests that using a combination of three approaches is appropriate to quantitative representation in general: direct labeling, encoding, and the use of self-representing scales.

Direct labeling of quantities and ratios would seem to be an ideal solution for use in technical publications in ornithology and in field guides, since the information relevant to the image would be contained within the eyespan (see Tufte, 1990). Robbins et al. (1983) and Sibley

(2000) make some use of direct quantitative labeling, but use of this strategy is far from universal. The majority of popular field guides and technical articles bury quantitative data in descriptive text, often on a different page than the illustration (see Coe, 2001; King and Dickinson, 1977; Peterson, 1980, National Geographic Society, 2002). Other beautifully illustrated and informative guides do not report quantitative information directly at all (e.g., Dunne et al., 1988), and this is also lacking in a highly popular and authoritative undergraduate text in ornithology (Gill, 1995).

The design strategy of encoding, such as by color scale, is difficult to use in ornithology illustration since color is an important integral part of representation of the bird. However, one lay guide aimed at advanced novice birders incorporates a series of symbols with each species' image, each symbol encoding information about nest locations, nest type, egg markings, diet, foraging techniques, and parental roles of each gender (Erlich et al, 1988).

Self-representing scales, where an object of known size appears in the image, is potentially more useful in narrative painting, where the scaling object might itself add a dimension of information. Narrative bird painters who have used this technique to advantage include George Edwards, whose *The Dodo and the Guinea Pig* (Edwards, 1758) emphasize the imposing mass of this extinct bird relative to a passing guinea pig; some paintings of birds, nests, and eggs where each item is properly scaled relative to the others, such as Reinhold's *Karoo Prinia* (in Levaillant, 1801), and Jan Christian Sepp's *Nest of the Black-crowned Night Heron* (in Nozeman et al., 1789). Alexander Wilson's plate of mixed species of Atlantic shorebirds (in Wilson, 1878) shows relative size of the birds more consistently than do many modern field-guide plates, and Audubon does an accurate job of scaling food items such as berries, grubs, and flying insects to his birds (see Audubon plates in Audubon, 1856).

Poor and inaccurate examples of scaling are also abundant throughout ornithological painting. George Edwards' *American Redstart* is depicted surveying a butterfly larger than itself (in Edwards, 1743), and Wilson's plate of a raven and two species of vulture includes a dead lamb equivalent in size to the birds (in Wilson, 1878). Many otherwise excellent field guides also neglect or distort scale in mixed species plates, where the relative sizes of different species are at best approximated. Absolute measurements are generally provided in descriptive notes, but this information is not useful in visual construction of the bird, especially to a novice. The scaling of reproductions in these guides appears somewhat capricious, and may be more a function of economy or convenience than of informational integrity.

Stimulating Reasoning with Ornithological Images: How Images Prompt and Answer Questions of 'How?', 'Where?', and 'Why?'

A data set, such as an image of a bird or other organism, is by itself an undifferentiated and messy mass of information. The intervention of the viewer's reasoning is required before the data becomes meaningful, for the painting cannot speak for itself, no matter how skillfully rendered it may be. Visual and statistical thinking on the part of the viewer must be called into play.

Tufte (1997) points out that cause and effect can be determined by reasoning about quantitative and qualitative evidence. This can be difficult to bring about in self-contained imagery, such as that of natural history subjects. Visual comparisons, or presentation of the unlikely, might be used to stimulate such reasoning. Consider a visual device such as a cartoon of a man with wings ten times the length of a jumbo yet; the length that would be mechanically necessary to keep the average man aloft. Such a ludicrous and unlikely image might force reasoning about 'why' a bird such as a Chimney Swift can spend three years continually

airborne, with wings that are only 70% the length of its body. This question ultimately finds causal explanation in the specialized anatomy and physiology of birds.

Visual declarations of cause and effect are rarely encountered in ornithological images. Descriptive narrative, where ornithological illustration is for the most part classified, begins to approach causal explanations when the viewer is forced to pause and ask, “Why?” Frequently encountered images in this field depict hummingbirds feeding on the nectar of flashy and brightly colored flowers, or a raptor with a snake or small mammal in its talons. A scale drawing or label showing the food indicate required to maintain an individual of a given species for a day would raise some interesting questions about energetics, that in turn would provoke causal explanations.

A time series – implicit or overt – simply reports data (Tufte, 1997). Forcing a comparison between images depicted at different moments in time raises a deeper question, i.e. “Compared with what?” A difference, once recognized, raises the causal question “Why?” Francis Lee Jaques’ paintings of birds migrating across extensive landscapes raise questions about both migratory behavior and the value of flocking to the individual (see Jaques, 1973). In a less dramatic fashion, the common illustrations showing changes in plumage as a species matures, typical of many field guides, also contain implicit questions, as do developmental illustrations in textbooks, and paintings depicting two generations, such as those showing parents tending eggs or young.

The inclusion of contrary cases that do not fit the general pattern of data serves to challenge generally accepted explanations (Tufte, 1997). In a mixed species plate or painting, inclusion of a bird where the bill morphology is atypical of its family may reach beyond ecomorphology to invoke an evolutionary explanation at a deeper level of theory. Clear and

undeniable links between bird morphology and habitat do exist and are easily recognized, but contrary cases can make it clear to viewers that correlation and causality are not necessarily the same phenomenon. Plates depicting members of the Cuculidae (cuckoos, anis, and roadrunners) with their differences in body shape, bill thickness, and behavior - despite the phylogenetic relationships that group them into one family are one of many fine examples (see Cuculidae plates in Sibley, 2000, pp. 267-270; Robbins et al., 1966, p. 172).

Where something is happening – such as in John Snow’s identification of the high proportion of cholera deaths occurring in the vicinity of a particular water pump in London (see Tufte, 1997, pp.29-34) – sometimes offers a clue about causation. Frequency distributions of bird species ( as in ‘rare’, ‘uncommon’, ‘occasional’ ‘resident’, or ‘winter visitor’ may alert the viewer or reader to the implicit question of ‘why?’, as might maps of the migratory patterns of different species. Maps of species distributions frequently supplement illustrations in bird guides and in technical publications in ornithology (see Coe, 2001; Howell & Webb, 1995; National Geographic Society, 2002; Peterson, 1934, 1980; Robbins et al., 1996; Sibley, 2000; also species descriptions in *The Auk*, *The Wilson Bulletin*, and *Birding*). Such supplemental images are of great value, since an aesthetically pleasing image depicting spatial aggregations of birds frequently cannot transmit sufficient information about wider geographical relationships.

Freeman Dyson (Dyson, 1992), in a collection of essays upon the nature of science and scientists states emphatically that “a great scientist thinks with his hands” (p.312), supporting the view that even the finest of illustration can never take the place of lab and field experiences, and implying that ornithological illustration has inherent limitations as an educational tool. This aside, images are informative and possess an educational benefit to students and scientists alike when they possess integrity and are revealing about causality (Tufte, 1997). The best images are

“documentary, comparative, causal and explanatory, quantified, multivariate, and exploratory” (p.53).

### The Revealed versus the Concealed: Escaping Disinformation in Ornithological Illustration

A commitment to integrity in illustration implies that comprehensive visual accounts must simultaneously depict both the revealed and the concealed. Ornithological illustrators presumably do not intentionally conceal the truth, but as in the case of Durer’s famous two-horned, armor-plated rhinoceros (Cole, 1953), have sometimes lacked complete or sufficient information. Historical examples include the frequent lack of scientific literacy on the part of the woodblock makers or engravers who were integral to the preparation of illustrations before the introduction of lithography in the late 19<sup>th</sup> century, and the secondhand and vague information given to painters of exotic birds, who frequently worked from nothing more than badly-preserved skins and anecdotes. Thus many historical examples of scientific images that contain poor and misleading information are the product of unfortunate circumstances that no longer plague the illustrator. Tufte (1997) examines the strategies of magic, which by intentional disinformation (not revealing the concealed), suggest what must be avoided in illustration or data displays when integrity is the goal.

One disinformation strategy that frequently manifests unintentionally in scientific illustration is that of allowing larger phenomena to mask the importance of relevant smaller phenomena. Naïve viewers are easily misled, and Tufte (1997) recommends that small telling details should be insistently pointed out or labeled. In narrative bird painting, this emphasis can be achieved by use of color, line, and compositional devices, as discussed previously. Field



guides have the option of labels, and Peterson (1980) uses a system of flagrantly conspicuous arrows to indicate important characteristics of the bird.

Showing an organism or phenomenon from one fixed viewpoint is another avenue to concealment; one that can be avoided where necessary by providing multiple and layered views (Tufte, 1997). This is the special power of diagrams and drawings over photography in illustration. A number of field guide illustrators do show birds in multiple planes and engaged in different activities. The most common strategy is the depiction of two views or two activities shown adjacent to each other on the same plate (e.g., Coe, 2001; National Geographic Society, 2002; Peterson, 1934, 1980; Robbins et al., 1996; Sibley, 2000). Before and after flap arrangements might also be effective, but appear to be non-existent in this genre.

With the exception of some anatomical drawings in technical publications, layering is rare in ornithological illustration, except where details of one part of a species' overall form has a difference in one characteristic that distinguishes the species, or the gender of an individual of that species. In such cases, layering appears as call-out details of the heads and bills in field guide portraits of such groups as the tubenose seabirds and the cormorants (e.g., Robbins et al., 1996, p.22, 37) and is also seen in detailed call out images of wing structure in the waterfowl (e.g., Robbins et al., 1996, pp. 39-9), and the tail feathers of the nighthawks and the nightjars (e.g., National Geographic Society, pp. 258-61). A popular college ornithology text (Gill, 1995) includes a variety of layered diagrams illustrating shared derived characters supporting hypothesized evolutionary relationships (p.51), details of flight feathers (p.66, 71), and some physiological mechanisms (p.142) and anatomical specializations (p.151). The advantage of expert layering is that information is offered to the eye and mind simultaneously, whereas

multiple views require separate diagrams; different paragraphs of activity in which time, space, or both separate the data (Tufte, 1997).

Tufte (1997) makes the point that properly placed text can also serve as an information layer, becoming an integral part of the diagram along with color and line quality. Field guide illustrations are typically well-supported with textual information, and for any given species generally include – at a minimum - data regarding the general morphological description, taxonomic placement within family and order, notes on similar species, verbal description of characteristic calls and songs, notes on range and typical habitat, and sometimes remarks upon juvenile plumage where this differs markedly from that of the adult (e.g., Coe, 2001; National Geographic Society, 2002; Peterson, 1934, 1980; Robbins et al., 1996; Sibley, 2000). Additional information in some texts covers diet, migration, and other behavioral notes, relative abundance and conservation status of the birds (e.g., Coe, 2001). Sibley (2000) provides more detailed morphological descriptions and addresses the issue of individual variation to a greater extent than do most other beginners' texts. Robbins et al. (1996) also represents songs by typical sonograms, in addition to verbal descriptions of vocalizations.

More specialized guides for the advanced novice (e.g., Dunne et al., 1988; Kaufmann, 1990) extend species descriptions to include social behavior, feeding habits and predatory tactics, morphological, behavioral, and ecological connections between species, and extensive notes on morphological variations with age and geographic region. *The Birder's Handbook* (Erich et al., 1988) is specifically intended for the 'birder' ready to move beyond identification of species into more profound biological knowledge, and contains impressive amounts of condensed and encoded data describing (in addition to the standard information covered previously) details of nest building, nest height and location, relative parental contributions by gender, descriptions of

the eggs, size of clutch, and incubation system, breeding system, developmental stages of the eggs and young, differences in diet in and out of the breeding season, and typical foraging techniques. The coded data is expressed in a summary line and followed by treatment paragraphs giving expanded information upon each category, and references to essays and data sources pertinent to each species.

These popular guides contain a great deal of similar basic information, but differ widely with respect to the accessibility of the textual information, and the integration of this data with the illustrations. Peterson's (1934/1980) guide retains a place as the best-selling and most widely known beginner's guide, and places the textual descriptions on pages adjacent to the illustration, a practice followed by Coe (2001) and the National Geographic Society (2002). The latter books improve upon Peterson somewhat by also including range maps on the adjacent pages, rather than by collecting these in a separate section at the back of the book. Sibley's practice of including textual information on the same page as the species' illustration more closely approximates Tufte's ideal of integration text and image, although this advantage is somewhat mitigated by a perceptually disconcerting columnar layout, rather than the more natural horizontal arrangements of text and image advocated by Tufte (Sibley, 2000; Tufte, 1990, 1997). Guides intended for the more advanced novice depart from standard layouts and pay relatively less attention to ease of access to information. Textual and visual data are less closely related in such works (e.g., Dunne et al, 1988; Kaufmann, 1990), with the text and illustrations frequently on succeeding rather than adjacent pages.

One important dimension of information that should be included in a full and revealing description of a given bird species is its characteristic flight pattern. This is of concern since such variables as the pattern of wing beats are important factors in recognition. It is difficult to

adequately represent motion on a two-dimensional surface, yet birds move frequently and one cannot truly know a bird species without a grasp of its flying behavior. Identification of some species in the field is almost wholly dependent upon such knowledge: raptors, for example, are frequently identified by flight patterns as they soar overhead (see Dunne et al, 1988), as are many species associated with pelagic and estuarine habitats (see Peterson, 1980, pp 74-104). The diving motion of ducks is also an important characteristic for species recognition from a great distance (Sibley, 2000, p. 97).

The depiction of motion is important to bird recognition in the field, and also to encourage a feel for the individual species' gestalt. Motion may be depicted in illustrations by ghosting, blurring, lines that track movement, and also signaled by showing the organism in varying postures. Although motion attracts attention, it also diminishes visibility. A still diagram should thus always be included, where details and important field marks can be indicated unambiguously. In field guides, flight is typically represented by one or two flight silhouettes – generally one ventral and one canonical view – supported by textual description (see Coe, 2001; Dunne et al., 1988; Kaufmann, 1990; National Geographic Society, 2002; Peterson, 1934, 1980; Robbins et al., 1996; Sibley, 2000). Gill's (1995) ornithology text utilizes ghosting to represent wing motions of hummingbirds in forward, backward, and hovering flight (p.107) and display behaviors of herons (p.219), while lines tracking movement are used to indicate migratory behavior (p. 289, 295) and the 'vee' formation of flocks of geese (p.101). The best depictions of flight in narrative painting show many different postures, such as Jaques' famous *Snow Geese* (Jaques, 1973), showing several hundred birds in flight over a marsh, conveying a sense that no single wing is misplaced.. Other paintings by Jaques, such as *White Ibis* (Howell, 1932) and *Canvasbacks* (Jaques, 1939) exemplify two critical points in the

depiction of bird flight. First, the accurate depiction of flight characteristics requires that the artist has an extremely deep knowledge of the species illustrated, not only its characteristic field representation, but also knows anatomy and the details of the specific flight feathers employed for singular purposes. The second point concerns design strategy; that motion is more effectively depicted against large areas of open space, a strategy that the 'Big Sky' artist used consistently to great advantage. These points are demonstrated nicely by a comparison of the paintings of the Common Nighthawk by J. Fenwick Lansdowne (in Livingston, 1968) and John James Audubon (in Audubon, 1856). Lansdowne shows his nighthawk in pursuit of a flying insect, against a subtly washed large open area, which each flight feather emphasized and rendered in exquisite detail. Audubon's nighthawk, also pursuing flying prey is also competently rendered, but the feathers are less detailed, and the addition of foreground foliage and the figure of a perched female below the aerialist, diminishes the sense of the bird shooting through space (Pasquier & Farrand, 1991). As Tufte (1990, 1997) insistently emphasizes, the controlled use of negative space and restrained use of secondary structural elements is critical to the impact of the primary subject.

Concealment apart, other forms of disinformation in illustration may be due to the introduction of noise that diverts the eye from content. The activation of negative space by frames or irrelevant background content is a source of such cognitive diversion. As discussed previously, this is rarely a problem in modern field guides or most narrative painting of the past two hundred years, but does appear historically in some decorative paintings. Thus the major design problem in ornithological illustration is how to reveal the maximum degree of information regarding the subject to be illustrated, and also the clarification of the complex. Tufte's recommended solution here is the PGP (particular-general-particular) approach, where

the illustration highlights a particular relevant detail or data point, then describes the general architecture of the data or subject, finally reinforcing the general with a second particular (Tufte, 1997, pp 68-9). Thus two particulars highlight and help to explain the general data arrangement. PGP is ideal for quantitative data displays, but its potential for use in natural history illustration lies in the arrangement of plates depicting different but related species. Field guide illustrator David Sibley also utilizes an effective within-species layout using this strategy. *The Sibley Guide to Birds* (2000) contains many single species plates showing eye-catching flight silhouettes at top (particular #1), with a larger side profile portrait of the bird in a typical posture underneath (general), while the bottom of the plate shows another detail indicating important features of the head, bill, tail feathers, or feet (particular #2). Certain of Sibley's woodpecker plates (see p.316-8 in particular) are exemplary.

#### The Design Strategy of the Smallest Effective Difference

A principle of visual explanation expounded upon at length by Tufte (1997) holds that displaying small differences allows for the display of more differences, resulting in illustrations that contain “a graceful richness of information” (p.7). The design strategy of displaying the smallest effective difference requires the illustrator to gently emphasize “just notable” (p.73) differences in elements of the illustration, showing minimal differences in a clear and effective fashion.

The smallest effective difference indicates design procedures of secondary and structural elements of illustrations (Tufte, 1997). Color and pattern encodes information in many bird species, and attention of the viewer should not be distracted from these relevant details. If secondary elements – such as fill around a technical bird portrait, or surrounding vegetation in a narrative painting – are muted, visual clutter will be minimized and primary information clarified

as a result. Contrasts in the secondary elements – e.g., landscape details – should be minimized, producing a visual hierarchy with “layers of inactive background...calm secondary elements...and notable content” (p74.). Further, strong contrasts between the secondary elements and the background tend to visually activate the background and draw the eye away from the subject. Thus one rule for judging an ornithological illustration in terms of didactic quality is the degree to which important details about the bird are emphasized. If this visual hierarchy is absent, the illustration loses power to instruct and inform, for as Tufte states, “when everything is emphasized, nothing is emphasized” (p.74). Adding sufficient text to support the illustration is another crucial tool of revelation and explanation, and adds credibility to the image, as the illustrator is explicit about the content that he or she intended to convey.

The revelation of differences that have explanatory properties may also be achieved by strategies of visual parallelism that serve as “visual analogs to syntactical and rhetorical principles (Tufte, 1997, p 79); strategies that rely upon the use of visual repetition and change, comparisons and surprises. Paired images are one strategy to reveal differences, enforcing contrasts to make key points. This strategy is used extensively in field guide plates, where male and female birds of a species in winter and summer plumages, juvenile and adult plumages, and eastern and western varieties of a species, are frequently displayed as horizontally paired images (e.g., Coe, 2001; Howell & Webb, 1995; National Geographic Society, 2002; Peterson, 1934, 1980; Robbins et al., 1996). This is spatial parallelism, which takes advantage of the human capacity to compare and reason about multiple images that appear simultaneously within the eyespan (Tufte, 1997); a strategy which is capitalized upon by field guide plates that employ multiple overlapping images to demonstrate variation within a given species.

Parallelism as a general strategy is one that uses any device to connect visual elements, positioning the viewer's mind to build connections between elements by means of position, overlap, orientation, synchronization, and similarities in content, as like is connected to like (Tufte, 1997). Congruous structures across multiple images give the eye and mind a context for assessing, evaluating, and explaining variation in data. If the negative space between the multiple images is consistent with respect to size and shape, the parallelism is further reinforced, allowing the relevant information to become even more coherent to the viewer. In publications containing ornithological illustrations, parallelism – whether by paired images, multiple images, or synchrony of negative space – is of especial utility where the intent is strictly didactic, such as textbooks and taxonomically oriented field guides

Natural History and Ornithological Images as Visual Confections: Stimulating Reasoning by Making Sense of the Apparently Disconnected

Tufte (1997) describes a confection as an assembly of many visual events. In contrast to other strategies described and recommended in Tufte's writing, the visual confection is not designed or intended to aid the viewer's understanding or reasoning directly, but instead confronts him or her with a mélange of unrelated subject matter. The educational value of such compositions is that the viewer is forced to energetically confront his own mystification, and construct some sort of meaning or explanation for what he sees.

Historically, visual confections have been quite popular in ornithological illustration, some taking the form of visual lists, and others mixing humor, aesthetic experimentation, and information. The friezes of the Egyptians are confection-like in quality as they blend symbolism and selectivity to represent a cultural ideal of a leisured rural life (Talbot Kelly, 1955). The Mughal court painters, otherwise under strict control of the Emperor, also blended symbolism and a cartoonist's wit to produce such confections as Miskin's *The Raven Addressing the*



*Assembled Animals* and *Noah's Ark* (Jackson, 2002). Persian artists also had a tradition of placing animals in confections intended to represent fables or illustrate poetry, such as the miniaturist painter Habib Allah's *Concourse of the Birds*, one of four paintings illustrating the 13<sup>th</sup> century Persian poem *The Language of the Birds*, and showing the unlikely assembly of a parakeet, crow, crane, grebe, heron, peacock, and stork gathered to discuss the means of reaching paradise (Jackson, 2002; Pasquier and Farrand, 1991).

In the middle ages, illuminated manuscripts such as the Alphonso Psalter, the Bird Psalter, and the Prayer Book of Bonne of Luxembourg served as visual lists of birds that served as religious symbols (Jackson, 2002; Klingender, 1971; Yapp, 1981). Francois Martinet broke away from the 18<sup>th</sup> century mode of didactic bird portraiture when he chose to show birds in architectural rather than natural settings, e.g., irreproachably rendered sparrows set against Parisian rooftops and cathedral spires, and an elegant cockatoo perched upon a gilded candelabrum (Martinet, 1795). Other, less humorous and experimental, but more didactic visual confections within ornithological illustration describe interactions between the bird and its environment, such as Grayson's portraits of Mexican birds against scenes that incorporate village life, as well as showing local flora and fauna (Stone, 1987). Some utilize call-outs to clarify information and to give examples or show variation, as in Sophie Webb's children's book *My Season with Penguins* (Webb, 2000)

Tufte (1997) frames the ideal visual confection as one that describes all aspects of its subject, blending text and images as, "verbs, acts, consequences" (p.126). As a confection combines assorted images into a fanciful construction, such a design strategy offers the potential to show "all at once what has never been together" (p.127), whether the approach utilizes

compartmentalization of images, or shows imaginary scenes. A combination of approaches is also possible, where imagined scenes are compartmentalized.

The visual confections would not be the design strategy of choice for the field guide or technical publication, since such an approach is a poor fit with taxonomic schemes. However, where they are appropriate, in addition to inherent aesthetic pleasure, such designs promote two educationally valuable results. First, the viewer is forced to consider what is happening within the confection, and then to construct an explanation for himself where the content is not obvious (Tufte, 1997). Second, the unfamiliar juxtaposition of information forces the practice and improvement of visual literacy. A related potential disadvantage of the visual confection is that interpretation of confections requires instructed viewers, or a willingness to struggle with unfamiliar material. Naïve or less motivated viewers may be left mystified, and gain little benefit from the study of confections.

#### Final Words: The Ultimate Aim of the Scientific Illustration

A bewildering variety of design issues, and possible solutions in terms of approaches, as discussed by Tufte in his three-volume theory of design strategy for scientific graphics, has been presented here. Means and ends may easily be confused, thus it is appropriate to close with a quote from this author reminding of the ultimate aim of the scientific graphic, and one that also offers a clear criterion for judging such artwork: “What is to be sought in designs for the display of information is the clear portrayal of complexity. Not the complication of the simple; rather the task of the designer is to give visual access to the subtle and the difficult – that is, the revelation of the complex” (Tufte, 1983, p.191).

## The Use of Illustration in Biology Education at the High School and College Levels

### The Special Power of the Natural History Illustration

When an audience encounters an effective graphic of an unfamiliar organism, individual lives are potentially affected by this new knowledge - lives which may be culturally, geographically, and historically far removed from the circumstances under which the organism exists or existed. Images of organisms, in particular, serve the purpose of allowing the non-scientist access to a biologist's way of seeing; a point in favor of the use of art in the science classroom and in public education (Janovy, 1985/1996). This same author cites George Sutton's watercolors as serving as a "window through which the general public saw into the workings of a scientist's mind" (p34) as he describes the exhibitions of Sutton's Arctic field sketches and Mexican paintings at the University of Oklahoma, exhibitions that drew "shoulder to shoulder crowds"(p.34). In similar vein, Audubon's work caused tremendous public excitement in the 19<sup>th</sup> century, as did the publications of John Gould (Lambourne, 1987; Pasquier & Farrand, 1991). The paintings of Louis Agassiz Fuertes, which combine biological accuracy and artistic beauty to an extent rarely equaled today did much to popularize the pursuit of bird watching in the United States in the first decades of the 20<sup>th</sup> century, and since that time, an interest in birds has become the focus of many lives that are otherwise unconcerned with science.

Images of organisms may serve one or more of several functions. They may inform the viewer about characteristics of the species depicted, increase appreciation of the perspectives and methods of science, and may increase environmental awareness. Both Harry Robin (1992) and Edward Tufte (1983) claim that an image is better suited to accomplishing these objectives than text. Tufte's point is simply that an image is more efficient, for information transmitted visually tells a story faster - and is also more memorable - than that described verbally (Tufte, 1983).

Robin (1992) expands upon this claim, holding that while most scientific studies and reports are presented in a format too foreign and in language too unfamiliar for a student or layman to comprehend, even a relatively complex image of a biological specimen can be decoded by a non-specialist, and impart some of the nature, process, and objectives of science.

This relatively easy decoding of complex images is attributable to two factors. First, the aesthetic response to an attractive or intriguing image serves to engage the viewer with the scientific content. Second, as Aristotle pointed out, we think in images. A static image invites an intellectual response, and as the viewer sees into the image, both knowledge and personalized meaning are constructed; thus the benefits of understanding a given illustration of biological material reach beyond comprehension of the specific content (Robin, 1992). Unlocking the meaning of such images yields to the viewer a taste of the shared intellectual passion for organisms that has animated both the scientific community and many amateur naturalists for centuries (Janovy, 1985/1996; Robin, 1992; Wilson, 1984)

### Scientific Illustrations within Science Textbooks

The majority of student encounters with scientific images occur via the medium of prescribed texts. Textbooks at all grade levels are becoming more pictorial, and illustrations are assuming a pivotal role in instruction (Blystone & Dettling, 1990). Illustrations can affect the classroom performance of science students positively if adequate information is conveyed in an accessible fashion, and the students possess sufficient visual literacy to learn from images. Visual literacy is therefore a critical educational competence, given that an estimated 85% of all messages received are visual; either orthographic (consisting of written text) or iconographic, that is information is represented by pictures or diagrams (Doblin, 1980). Orthography is important to development of visual literacy since prose frequently calls attention to critical

aspects of an image. Iconographic images include graphs, charts, flowcharts, and symbols, in addition to the diagrams, line drawings, paintings and photographs that are the most characteristic of biological texts with a natural history emphasis.

A number of authors have traced the evolution of the use of illustrations in textbooks (see Blystone & Bernard, 1988; Duchastel & Waller, 1979; Lynch & Strube, 1985; Mulcahy & Samuels, 1987; Smith & Elifson, 1986). Mulcahy and Samuels (1987) note that illustrations intended to explain and enrich textual content appeared in the mid 19<sup>th</sup> century, and that the proportion of illustrations relative to text has increased as the emphasis of American educational methods has shifted from rote-learning to one that involves a sensory approach to acquiring and retaining information. A survey of introductory college biology texts published between 1950-1984 reported that the number of illustrations had increased 300 percent during that period, adjusting for the length of the book (Blystone & Barnard, 1988). An upper-level college biology text now has as many as 1,500 images, including charts, graphs, and line drawings in color, and this trend is also reflected in science texts at secondary levels (Blystone & Dettling, 1990).

This increase in the use of imagery does not necessarily indicate a corresponding increase in the educational value of the texts. Lynch and Straub's (1985) study of a century of science textbooks noted a shift in authorship, from clergymen to scientists to teachers to committees - with the result that texts now tend to be assembled rather than written (Thompson, 1984) - and note an accompanying tendency to narrow the rhetorical focus toward descriptive science, and away from the incorporation of science into wider life experience. Thus although texts now incorporate more graphics, the textual content of the books does not support a general integration of scientific knowledge into the students' experience (Blystone & Dettling, 1990). One problem with the expanded use of illustrations in science textbooks is that students – along with the

majority of the public who are not professional artists, designers, or architects – are not fluent in iconography as a language; and are ‘semi-literate’ in visual terms (Doblin, 1980). Thus visual literacy is an important issue in science education, as the content of texts becomes increasingly iconographic, and if an increase in visual information is to have an appreciable effect on learning, visual literacy must be expanded.

#### Developing Visual Literacy in the Users of Image-rich Textbooks

Science educators and educational researchers have suggested a number of methods by which teachers may develop visual literacy in students. Gwyn (1987), Scruggs and Mastropieri (1985) and Szlichcinski (1980) each suggest different approaches by which illustrations might be used more effectively. Each of these methods is founded upon increased interaction and engagement with the material, and encouraging students to develop their own visual representations of the material studied. Alesadrini and Rigney (1981) refer to this technique of student-produced images of text and knowledge as ‘induced picture strategy’ and hold that these induced pictures assist with effective interpretation of imposed pictures (those prepared for the student). Whether visual representation of content knowledge by the student is helpful or not, Wandersee’s (1988) study of college students across four grade levels indicated that only a minority of students attempt to construct visual aids of their own as they study. Blystone (unpublished observation in Blystone & Dettling, 1990) reports a reverse approach to increasing the visual literacy required for illustration-dependent learning that he has found successful with college students. Blystone’s approach involves having his college students translate a complex illustration back into words, assisting realization of the density of information contained within the image.

Evaluating the visual-literacy base of a class, the complexity of the illustrations offered to the students, and awareness of the content knowledge required to deal with the illustrations presented are also appropriate strategies for instruction incorporating the use of images. Cueing the students with verbal or written instructions may be helpful in directing students through critical illustrations. Holliday's study of the effectiveness of learning biogeochemical cycles from picture-word diagrams indicates that written instructional support for interpretation of diagrams should be complete and thorough, or not attempted at all (Holliday, 1981). This study utilized a pre-post test design, and four learning protocols among matched but randomly grouped tenth-grade biology students. The protocols were designed as follows: a picture word diagram accompanied by 20 study questions; the identical picture-word diagram accompanied by 5 study questions; the identical-picture word diagram with no questions to cue study of the illustration; and a prose passage describing the biogeochemical cycles illustrated, but with no supporting diagram. Holliday found that the highest post-test performance occurred in the students given 20 questions supporting study of the diagram, and also in those given no cues at all, indicating that thoroughly supporting a student's perusal of an image is effective, as is forcing the student to devise his own approach to the image. Provision of partial text to support illustrations is associated with incomplete study of the image.

#### Matching Scientific Illustrations to the Visual Literacy of the Student Audience

While the graphic content of science texts continues to increase, textbook critics (e.g., DeSilva, 1986; Fiske, 1984; Gabel, 1983) have focused their attention on the quality and content of the prose, and have failed to analyze the accuracy, clarity and appropriateness of illustrations for the student reader for whom they are intended (Blystone & Dettling, 1990). Blystone and Dettling recommend that three issues be examined in the evaluation of an illustrated science text.

Sufficient interplay between prose and illustrations should be present, the information content of the images should be adequate and appropriate, and the illustrations should be a good match for the cognitive development and experience of the students. With respect to the connection between prose and image, these authors report that texts infrequently refer to relevant illustrations, possibly because texts and graphics are developed independently during the process of textbook production, and in some instances where an illustration is supported by textual references, such references may be misleading or actually incorrect (Blystone & Dettling, 1990).

Blystone (1987a) surveyed all high school biology texts in use in 1984, finding that all contained inconsistencies between text, labels, and images; reinforcing the conclusion of Marek (1986) that student misconceptions in biology may develop – at least in part – from the textbook used. For example, an illustration of cell structure clearly shows the nuclear envelope where two membranes surround the nucleus, yet both label and text refer to a single nuclear membrane (Blystone & Dettling, 1990). Students utilizing the textbook apparently resolved the contradiction by identifying the nuclear boundary with a single membrane, for upon reading these students' essays on plant cell structure for the AP Placement in Biology, Blystone found that three-quarters of the essayists adopted the imprecise terminology of the text.

Blystone and Dettling (1990) indicate that the majority of illustrations in high school and introductory college biology texts are sufficiently complex and information-dense, and that diagrams of cellular structure and cellular processes may represent a number of time periods and discrete events. This complexity – in itself laudable and a criterion of excellence in scientific illustration (see Tufte, 1983; 1990; 1997) – raises some pedagogical problems with respect to the literate use of these images. Students may not be equipped to extract the information contained, either because of a lack of visual literacy skill, or/and due to insufficient content knowledge.



Both students and instructors may be unaware of the time investment required to probe the content of, and benefit from, an information-dense graphic (Blystone and Dettling, 1990).

This mismatch between illustration and viewer comprehension is the third issue to be considered in the evaluation of the illustrated science textbook (Blystone & Dettling, 1990). Whereas it is reasonable that a scientific graphic require some time investment and present a moderate cognitive challenge, interpretation of the graphic should be within the capabilities of the student. In developing textbook prose, publishers apply precise readability and general interest measures to ensure the text is matched to the grade level audience; measures not applied to the effectiveness and readability of the graphic content of the same book. A comparison of five high-school texts' treatment of membrane structure and the fluid mosaic model found that the reading difficulty level of the prose fluctuated by no more than two grade levels, yet the level of visual comprehension required to interpret illustrations varied from middle school levels through introductory college courses, reflecting an ability difference of six grade levels. Thus the information content of any given illustration might have either intellectually undermined the 10<sup>th</sup> grade student for whom the text was intended, or left him or her convinced that membrane structure was an impenetrable mystery. For visual learning to be maximized, the complexity of the illustration should also be matched to the content knowledge of the student or viewer, and along with the prose content of instructional materials, illustrations require analysis with respect to accuracy, clarity, and information content (Blystone & Dettling, 1990).

#### Goals and Objectives of Environmental Science and Ecology Curricula

The historical roots of the study of environmental science and ecology can be traced through Aristotle, Buffon, Wallace, Darwin, through others who observed and noted relationships within the natural world and collectively established the discipline of ecology

(McComas, 2002). In particular, German biologist Ernst Haeckel developed a substantial portion of the modern conception of ecology at the end of the 19<sup>th</sup> century (Haeckel, 1866).

Natural history is at the base of both the science of ecology and environmental education; two disciplines that merged in the latter half of the twentieth century (McComas, 2002). In 1891, Wilbur S. Jackman published *Nature Study for the Common Schools*, establishing the rationale for the inclusion of many ecology related concepts in the science curriculum. Groups like Harvard's Committee of Ten added to the rationale for nature study, and writers such as Anna Botsford Comstock and Liberty Hyde Bailey provided the instructional materials needed to support the study of nature in the schools. Comstock's *Handbook for Nature Study* (1939/1986) went through 24 editions and is still in print (McComas, 2002). McComas (2002) points out that natural history is unusual in science since many of these historical materials retain a great deal of relevance: "...the clouds of today differ little from the clouds of yesteryear and frost forms for the same reasons it did earlier in the century" (Rockcastle in foreword to reissue of Comstock, 1939/1986, viii).

Later in the 20<sup>th</sup> century, the birth of environmental activism and heightened public awareness to environmental issues following the publication of *Silent Spring* (Carson, 1962) and *The Population Bomb* (Ehrlich, 1968) - with the inception of Earth Day a few years later - resulted in ecology becoming an established part of the school science curriculum, along with other recently developed sub-disciplines such as molecular biology (McComas, 2002). However, science educators have not unequivocally described the ideal curriculum for ecology and environmental science in terms of goals, content and process. McComas' recent review (2002) attempts to synthesize the issues comprising this problem in terms of the various

rationales for ecological education, a number of expert perspectives, and the *National Science Education Standards* (NRC, 1996).

Rationales for ecology education support the study of organisms and their interactions with the environment as worthy curricular elements. Pedagogically, the study of ecology contributes to learning and also makes demands upon the learner (McComas, 2002), as it allows application to life and demands synthesis of a number of previously acquired concepts. McComas holds that in this respect ecology is the most sophisticated, synthetic, and high-level pursuit within the domain of biology. Ecology equals the study of evolution as a synthetic area that is at once informed by, and yet is a necessary foundation for, other areas of biology. Thus the study of ecology leads the student to a view of biology as a rich web of interrelated ideas rather than a collection of concepts and facts, and has potential for improving learners' conception of the nature of science, especially important to those students whose life and career paths will otherwise isolate them from scientific thinking and practice.

In addition to these pedagogical advantages, ecology has much inherent interest. Nature study is attractive to most young children, and the study of relationships between organisms is an intuitive continuation of this appeal to inherent biophilic tendencies in older students (Kellert & Wilson, 1993; Wilson, 1984). Ecology also involves use of interesting laboratory techniques and appealing field activities, leads to consideration of concepts of energy flow and interspecific relationships, and also the practical application of ecological causes and consequences to environmental problems (McComas, 2002). This last effect of studying the natural environment may have the most profound impact upon students of any area of science content. As students become engaged with the environment and understand organisms and processes, and apply what

they have learned to their surroundings, the potential to understand many of the interactions between science and society becomes manifest.

### National and International Perspectives upon the Goals of Environmental Education

Attempts to formalize the goals of environmental and ecological education have been made since these fields have succeeded nature study in schools (McComas, 2002). The first definition came from William Stapp at the University of Michigan in 1969, stating that the aims of environmental education should be to produce a citizenry knowledgeable about the biophysical world, aware of environmental problems, and motivated to work toward solutions (Stapp, 1969). The Environmental Education Act of 1970 stated the purpose of environmental education in rather anthropocentric terms, describing this as understanding man's relationship with his surroundings, "the relation of populations, conservation, transportation, technology, and urban and regional planning to the total human environment" (United States Public Law 91-516). In the 1970's, three international gatherings – the 1972 Conference on the Environment in Stockholm, the 1975 International Workshop in Belgrade, and the 1977 Intergovernmental Conference on Environmental Education in Tbilisi, Republic of Georgia – drafted position papers on environmental and ecological educations. The Tbilisi recommendations reflected a view of the environment that considered the biological world of intrinsic interest and importance, put emphasis upon the background content skills required to understand environmental issues and declared that environmental education should aim to equip the individual with "skills and attributes needed to play a productive role towards improving life and protecting the environment with due regard given to ethical values" (UNESCO, 1900, p.26-7). The Tbilisi group also emphasized that to create new patterns of behavior with respect to the environment, environmental science education and ecology should not be elitist or elective, or restricted to

certain grade levels in certain schools, but should be delivered on a world-wide, multicultural level to all people.

The Tbilisi declaration formed the basis of a curriculum framework for environmental education suggested by Hungerford et al. in 1980, which included ecological concepts as background, increasing awareness of environmental issues, development of investigative and data-gathering abilities, and planning and implementing environment policy. A decade later, the National Environmental Education Act of 1990 (United States Public Law 101-619) established an office of environmental education in conjunction with the Environmental Protection Agency, and provided some funding for environmental education training programs, grants, and fellowships. In addition to this federal support, there is a “grassroots” environmental constituency in the form of a wide range of interest groups – such as Ducks Unlimited, The Audubon Society, recycling groups – that offer local support to environmental education programs, and also work to increase public awareness of ecological and environmental issues.

#### Educators’ Views of the Ideal Ecological Curriculum: Identification and Correction of Initial Misconceptions

The constructivist view of education holds that a student’s current knowledge and understanding is the foundation of his or her future understanding (Deboer 1991; Mintzes et al., 1997). Thus attempts to develop ecological and environmental curricula must include a consideration of what students know about the natural world, and also their typical misconceptions and views at odds with the scientific perspective. Instruction can then be based upon current knowledge and address likely misconceptions.

Krebs (1999) reviews naïve views of ecology held by the general public, finding these to be principally a lack of understanding of the interdependence of species, believing that some perfect balance of species is natural, and a lack of understanding of the processes of succession.

The science of ecology also tends to be confused with environmental problems affecting humans, such as overpopulation, depletion of energy reserves, and toxic waste disposal. Munson (1994) provides a synthesis of empirical studies of student knowledge (including that of young children, high school students, preservice teachers, and foreign students) of basic ecological concepts. This synthesis indicated that the topics generally misunderstood are those dealing with relationships within ecosystems, such as food webs, energy cycling, and the transformation of nutrients and pollutants as they move through food chains. Population biology was also subject to much misunderstanding, particularly with respect to the links between population size and resource availability, and the causes of extinction. Again, much of the misconceptions about population size and carrying capacity could be traced to a lack of understanding of the links between organisms in an ecosystem, particularly the belief that the only organisms in a system of importance to others are those species that serve as prey items (Griffiths & Grant, 1985).

Targeted ecology instruction might appear to be the answer to correcting student misconceptions. However, Marek's (1986) study of the effect of instruction upon specific misunderstandings of the food web concept indicates that such presentations have limited effect; 57% of the students who received this instruction persisted in their misunderstanding, and only one student of 58 in the study demonstrated sound understanding of the concept.

McComas (2002) questions whether traditional instruction is an effective method of changing persistent misconceptions. It is here that the extensive use of imagery might be helpful: one major difference between expert and novice problem solvers is that experts possess the ability to form an image of a situation (Ambron, 1988), and firsthand experience with a situation in the field or laboratory is an ideal route to such visualization. Although the use of images cannot replace direct knowledge of specimens or phenomena gained in laboratory or field

experiences, and may not have the same degree of potential to stimulate a lifetime interest in science (NSTA position statement in Klein et al., 1982), the cost and logistics of providing these experiences may prohibit their being made available to students, and learning from images has been shown to provide better understanding and retention of concepts than information delivered via lectures or reading materials. Woods (1989) cites data indicating that 90% of concepts encountered via real or simulated activities are recalled over the long term, compared to 30% of those encountered via images, and only 10% for those ideas delivered via lectures or reading materials.

#### Expert Views of Important Concepts in Ecology and The Potential for Image Use in Teaching Such Concepts

Cherrett (1989) surveyed members of the British Ecological Society and constructed a list of the top 20 most important concepts in ecology, ranked in importance by these distinguished biologists. Of the listed concepts, the ecosystem, energy flow, niche, competition, life-history strategies, ecosystem fragility, food webs, ecological adaptation, limiting factors, and predator-prey interactions might all be introduced via natural history illustrations, especially those of the narrative ‘organisms-in-environment’ school.

Environmental science coverage in the *National Science Education Standards* (NRC, 1996) is scattered in narrative form throughout the document, and is grouped into a thematic area linked to grade level. Thus the theme “populations and ecosystems” is found within the Life Science area for grades 5-8, and “natural resources” within the area of Science in Personal and Social Perspectives for grades 9-12. Using a reductionist qualitative analysis, McComas (2002) identified 40 ecology related items in the NSES narrative. Examples are “...humans modify the ecosystem...” (NRC, 1996, p.186) through population and pollution, etc. and “All organisms cause changes in the environment in which they live” (NRC, 1996, p.129). Overall, the

*Standards* primarily target anthropocentric issues of population, limits on growth, and the impact of humans and other organisms on the environment, while urging that environmental decision-making be guided by science and technology. The ecology topics included in the *Standards* that might effectively be introduced or reinforced via ornithological illustration are: food chains and energy flow, the impact of organisms on each other and the environment, interactions between organisms such as predation and competition, and human impact upon other species. The process skills that might be effectively taught with the use of ornithological images are described under ‘Abilities Necessary to do Scientific Inquiry’ and ‘Understandings about Scientific Inquiry’ (NRC, 1996, Science As Inquiry, Content Standard A), and also ‘Science as a Human Endeavor’ and ‘Nature of Scientific Knowledge (NRC, 1996, History and Nature of Science, Content Standard G). These process skills are also extensively recommended and described by the American Association of Science’s *Benchmarks for Scientific Literacy* (1993)

The NRC *Standards* take a “spiral and integrated approach” to ecological material (McComas, 2002,p.272), and thus the ecological content is spread evenly throughout all grade levels, for the most part as a Life Science topic but also appears in Earth and Space Science, and in Personal and Social Perspectives. The topics of population ecology, food chains, energy flow, and human impact appear in all the grade levels addressed by the *Standards*. It appears that students would encounter these key concepts at increasingly higher levels of sophistication if this plan were followed, and McComas (2002) holds that environmental science instruction could be considerably enriched if teachers followed the recommendation of the *Standards* to teach science as inquiry supported by hands on activities.

The ecologically relevant content within the American Association for the Advancement of Science's Benchmarks for Science Literacy (AAAS, 1993) is referenced in Chapter 1, ‘The



Nature of Science’; Chapter 5, ‘The Living Environment’; and Chapter 12, ‘Habits of Mind.’

Content knowledge is covered in ‘The Living Environment, and includes all of the concepts listed by the scientists participating in Cherrett’s (1989) study, with a special emphasis upon interdependencies between species, and the mechanisms and results of evolutionary processes.

Process skills relevant to ecological studies are addressed in both ‘The Nature of Science’ (AAAS, 1993, Chapter 1), and in ‘Habits of Mind’ (AAAS, 1993, Chapter 12). ‘The Nature of Science’ benchmarks are primarily concerned with the idea that scientific knowledge claims are based upon empirical data that supports abstractions based upon initial observations, with particular emphasis upon the importance of reflecting and re-reflecting upon what is observed. A historical perspective is suggested to present the bulk of scientific knowledge as having grown incrementally as a result of continued observation and reflection, and to encourage attainment of a scientific world view – a notion that scientific knowledge is limited, fluid, and subject to continual modification. All the above imply the necessity and importance of relentless observation by the scientist, who must also develop the ability to discriminate between the trivial and the significant as he or she notes differences when making observations or assessing the results of observations. The benchmarks pertaining to the nature of science also stress that while the student should realize that progress in science is largely incremental, there exists a tension between this norm and the breakthroughs that may radically alter the character of knowledge. Participation in realistic scientific investigations is suggested by the *Benchmarks* as the optimum mode of inculcating an understanding of the nature of science in students, but the authors also consider the life-stories of scientists to be useful, and acknowledge the inescapable necessity for the systematic learning of certain concepts not amenable to the inquiry approach. Exercises that demand the student formulate predictions, and designs and carries out empirical tests of single

variables embedded in complex phenomena are also recommended, as are those that allow the weighing and comparison of competing explanations in the face of ‘hard’ data. Finally, the *Benchmarks* insist that science should be communicated to the student as an adventure in which all can participate, not as a specialized endeavor requiring professional status.

‘Habits of Mind’ (AAAS, 1993, Chapter 12) is concerned with the development of scientific values, attitudes, and thinking skills in students, which are of particular relevance to ecology and environmental science in that these habits improve both quantitative and qualitative problem solving abilities. The scientific values and attitudes espoused here include honesty and curiosity. Honesty is described as the willingness and ability to objectively observe, record, and report data, and also is the basis for a scientific attitude that comfortably and maturely incorporates both open-mindedness and skepticism, such that the scientist is willing to consider competing explanations while subjecting each to serious and implacable scrutiny. Curiosity, and the inclination and ability to formulate varied questions about observations is cited as a fundamental characteristic of the scientist, and is extended to a willingness to formulate and consider questions that are essentially unanswerable by empirical means. The *Benchmarks* emphasize that the scientifically literate individual places value upon all questions and hypotheses as having the potential to generate fruitful investigations.

Scientific habits of mind also incorporate the development of quantitative reasoning skills, and the ability to frame quantitative answers in a sensible and meaningful context (AAAS, 1993, Chapter 12). Skill in observation and manipulation should be developed, as these are integral to the actual practice of science, as are the thoughtful consideration of observations as the springboard to lines of investigation and the construction of new knowledge, the ability to

formulate explanatory models from observations, and a drive to develop a deep and integrated understanding of observed phenomena.

The scientifically literate must also possess a respect and appreciation for clear and accurate communication of ideas and data in writing, images, and speech (AAAS, 1993, Chapter 12). Critical response skills are also much lauded in the AAAS *Benchmarks*, where the individual is able to make sound judgments about assertions based on what is known (or unknown) about their character – an ability of considerable relevance to environmental policy and decision-making issues. Students should be taught to justify their own assertions, and always be able to frame a response to the question, ‘How do you know?’ The skills of critical response also incorporate the ability to construct different explanations for a given set of observations, and evaluation of the basis of the knowledge claims of others, identifying misrepresentations, incomplete or insufficient data and analyses of that data.

### The Inquiry Oriented Approach to Ecology and Environmental Science

The *National Science Education Standards* (NRC, 1996), the American Association of Science’s *Benchmarks for Science Literacy* (AAAS, 1993), and William McComas’ (2002) review of the ideal environmental science curriculum, are in agreement that an inquiry-oriented approach is optimal for teaching ecology and environmental science. Thus it is appropriate to review the inquiry approach to science in a general sense, and also to consider how and where the use of images may be useful in the inquiry oriented ecology curriculum.

Inquiry-based learning is frequently connected with realistic laboratory work and field experiences that foster motivation and understanding. Bunderson and Cooper (1997) hold that real-world contexts and problems relevant to students’ lives provide the motivation for the active student involvement in science that in turn results in a level of scientific literacy and critical

thinking skills necessary for them to make informed decisions about science-related issues (such as medical and environmental) that they will deal with as adults. These authors see field settings, particularly those involving a service component, as the best path to engaging students with science in a manner that enables them to understand the usefulness and connectedness of scientific knowledge.

While many educators laud the inquiry approach to science learning, Windschitt and Buttemer (2000) point out that if this instructional strategy is to be truly effective, the climate of inquiry is established only with considerable effort, and depends largely on the construction of inquiry questions whose use extends beyond the issue of being of personal interest to the students. Science must be about the intelligent formation of questions before it can arrive at answers, and if the inquiry-based science learning approach is to model scientific practice effectively, student scientists must frame questions, systematically search for answers, and then connect their resulting knowledge to that which is already known. Thus the inquiry-based science lesson has three phases: “exploring events in nature until a meaningful question emerges; probing the material world directly for an answer, and arguing the validity of that answer to an audience” (Windschitt & Buttemer, 2000, p.346).

Windschitt and Buttemer (2000) argue that questions posed by teachers lose much of their educational and personal value; when the question manifests via a third party, the resulting inquiry lacks personal meaning and no intellectual endeavor is required on behalf of the student. The inquiry becomes structured, with the implication that a single acceptable answer exists, and the students’ experience is thus constrained. These authors do concede that structured inquiry is useful when learners have little or no experience in developing testable questions, but hold that this approach does not adequately model real scientific practice. By way of contrast, “the act of

formulating a significant questions that is researchable involves the student in higher-order thinking...(taking the form of)...inferring from observations, making predictions from inferences, developing questions of significance, and forming testable hypotheses” (p.346).

The form of a significant inquiry question should be one that clarifies relationships, such as how a given occurrence varies with a specific event or property (Windschitt & Buttemer, 2000). For example, students have observed birds at a feeder; created hypotheses and predictions based upon these observations, and graphed results to indicate the nature of relationships (Whitin & Whitin, 1997). Such questions result in explanation, a more powerful response to an event or an image than mere description. The instructional difficulty lies in the counterintuitive nature of this line of questioning, which may require considerable and sustained prompting on the part of the teacher, who must relentlessly ask open-ended questions as a response to students’ initial observations, and challenge student predictions in such a way that the learner forms an idea of the nature of evidence required to answer his or her question. With persistent effort, the student should ultimately come to regard initial observations of events as the very beginning of a “sustained dialog with the natural world” (Windschitt & Buttemer, 2000, p.347). It is quite possible to conduct inquiry experiences in which the initial observations are collected ‘secondhand’ from images. Nolan and Nolan (1997) suggest that images of ecological interest in environments not easily accessible to students (e.g., old growth forests; local marshes; coral reefs) serve as case studies in ecological and environmental issues that student teams can examine and propose management recommendations for. If each student in the team represents an organization or interest group with different goals (industry groups, native Americans, commercial fishermen), they receive experience in collecting data and presenting arguments, a

valuable exercise in scientific methodology, nature of science, and relevance of science to the real world.

The second phase of the inquiry experience is answering the formulated question, demanding an understanding of the data that must be collected to yield an answer (Windschitt & Buttemer, 2000). When field and laboratory experience allowing for hands-on data collection is logistically impossible, students can create lines of argument based on images, and present these to the rest of the class, stimulating discussion about reasoning. If the data is to be collected from a search of images, the students must literally understand what to look for; they must be able to identify the dependent variable as a visual entity. The scale, or level of examination, of the dependent variable is relevant, as is making mistakes, running into dead ends, and realizing that one must redefine the question and begin the process over (Windschitt & Buttemer, 2000). This is where independent inquiry allows the student direct experience of the nature of science, where even the most sophisticated structured inquiry cannot: the frustrating but invaluable realization that a given data set failed to answer the question by nature of faulty experimental design, or that the question was inappropriate or simply unanswerable. Making a series of mistakes of this nature can encourage students to understand that the data they collect must flow from a testable question, and in turn, this data can only be as meaningful as the question for which it was collected.

Transformation of data, even crude groupings and reorderings may assist students in visualizing relationships of an ecological nature such as form and function, or where parameters of climate or habitat indicate relationships with diversity or certain morphological characteristics. Student-constructed images such as pie charts or Venn diagrams may show the distribution of characteristics that may be shared by otherwise different organisms (Windschitt & Buttemer,

2000). Visual and representational thinking is encouraged when students reflect on the relative advantages and shortcomings of diagrammatic and dimensional (graphs) displays of data, and begin to understand what each is capable of revealing. The capacity for meaningful representations of data is interactive: as students learn to think visually and represent their thinking on paper, they begin to understand how raw data alone may not reveal truth, and also learn to utilize data visually to support an argument. Vision is a way of knowing with which students are familiar, and encouraging them to create scientific knowledge through visual means/use of images creates self-confidence as creators of scientific knowledge. However, transforming and thinking through data sets requires considerable motivation, and Windschitt and Buttemer (2000) stress that the students will be more zealous in pursuing a line of argument and in examining and manipulating data if they have developed their own question initially.

The final phase of the inquiry experience, that of defending an argument, or arguing the validity of an answer or a line of reasoning, is considered to be the most important by Windschitt and Buttemer (2000), for it is here that the students review their thinking, look critically at the evidence they have amassed, and connect these results to existing knowledge. “No matter how elegant a question, or how adroitly or cleverly an experimental design supplies data to form an argument or answer, a student investigation is not a complete experience until those involved have defended their work to their peers. Convincing one’s peers of the validity of one’s findings, and justifying the question posed, forces a logical review of purposes and procedures, and a more piercing look at interpretations and conclusions” (p.249). The teacher can help the latter goal along by taking the role of the devil’s advocate and suggesting alternative interpretations and/or conclusions. This forced retrospection may also encourage a more consciously metacognitive mindset amongst student researchers in future experiments.

## How Images Have Been Utilized in Inquiry-Oriented High School and College Biology Classes

A survey of seven recent years issues of *The American Biology Teacher* (1996-2002) and *The Journal of College Science Teaching* (1983, 1985-1991) revealed that science classes and units incorporating the use of images fall into three general categories. The students may work with generating questions and obtaining information from imposed images, may construct images themselves to reinforce and demonstrate understanding, or both imposed and induced images may be incorporated into the class or unit. A variety of means by which images have been (or may be) utilized in by science educators is described in detail below.

### Use of Imposed Images in Inquiry-Based Science Activities

Illustrations may serve one or more of six purposes in biology education (Ryan, 1989): to describe what an object or phenomenon looks like; to outline steps in a process; to provide visual organization that facilitates recall; to illustrate changes, trends, and comparisons; to condense large amounts of data and information; and to make abstractions more concrete. In addition, the uses of images in science described here also suggest that increased engagement with the material, and increased internalized knowledge and awareness of the nature of science and the interconnectedness of scientific knowledge with that of other disciplines are additional fruits of incorporating the visual into science learning.

In a large introductory chemistry class at the University of Nebraska, Brooks (1985) reports that student concentration and engagement increased when instructors invested much time in preparation of elaborate artwork for slide presentations (showing instruments, chemicals, scientists, phenomena) and lecture notes were given to students as handouts, allowing them to engage with the image rather than frantically taking notes. A peripheral benefit was that the instructors reported that they enjoyed teaching the course more than they did the traditional



lecture format. Chowning (2002) reports upon increased engagement of high school students with non-scientific interests as they produced individual artwork for a biotechnology expo, with each student's work monitored for scientific content and understanding by a mentor-researcher from the biotechnology industry.

Film is a popular mechanism of using powerful imagery to introduce and/or reinforce concepts. Leroy Dubeck (1981) approached the problem of attracting nontraditional continuing education students into an elective physics course at Temple University by utilizing a science fiction film to illustrate the concepts and principles of each module of the course, after this information had been presented by the more traditional means of lecture and demonstration. A class discussion followed, which Dubeck was surprised to find "lively and extended." For example, the unit on momentum was reinforced by a showing of *The Day the Earth Caught Fire* (British Lion, England, 1962). Although the films accounted for a substantial proportion of class time, Dubeck discovered that students in this class retain concepts better than students in his more traditional classes, possibly because the visual medium had students become emotionally engaged with the content. The approach also worked affectively; not only was students' performance improved, but one-third of these non-science majors indicated that they would take further courses in physics.

Leonard et al. (1996) discuss an NSF funded curricular approach to the teaching of high school biology geared to encouraging interest in biology among students who are unlikely to continue their education. This curriculum (labeled *BioCom* for *Biology and the Community*) hoped to resolve the issues of engaging those students that the inquiry-oriented Biological Sciences Curriculum Study programs (BSCS, 1991) does not succeed with. Leonard et al. also believe that many biology teachers do not have the expertise or time to sustain the investigative

program recommended by BSCS, and that *BioCom* may provide an alternative. *BioCom* suggests less dependence on texts, that texts should be smaller than most of those currently in use, designed around important biological concepts and principles, and cover fewer topics in greater depths (Leonard et al., 1996). Although *BioCom* is in agreement with the *National Science Education Standards* (NRC, 1996) and the *AAAS Benchmarks* (AAAS, 1993) that a laboratory or field approach should be emphasized in the ideal biology program, it recognizes that this is impractical for many high school teachers (Leonard et al., 1991). The alternative offered by the *BioCom* program is a focus on selected concepts and technological applications of those concepts within the students' immediate community. One assumption of the *BioCom* curriculum is that ecology, along with evolution and genetics, is one of the core concepts of biology (Leonard et al., 1996), and for each topic presented, the instructional strategy allows for a total of 16-21 days, and each begins with an entire day of "compelling visuals" (p.10) such as pictures or videos to introduce the topic, followed by inquiry-based projects, and discussions and presentations.. The use of images here is to introduce topics that are then developed through guided inquiry, where the students develop their own meanings of science concepts through direct experience.

Two-dimensional images and video are the most popular mechanisms of visual engagement with science when field trips and other direct experience is unavailable. Direct field experience with many scientific phenomena and ecosystems is very limited for many classes, which may have easier access to museums. Biology educator Flannery (1998b) points out that the backdrops of museum dioramas have a special power of engagement, conveying a sense of wonder, as they invite the viewer intimately into a scene he or she is unlikely to see firsthand, and when video is inadequate to convey a sense of place. Philosopher of science Asma (2001)

emphasizes that evolution and ecology are dramatized in natural history worldwide by images in the backstage elements of dioramas. The manner in which images are used to convey scientific ideas in these diorama settings varies in approach: the Grande Galerie in Paris ignores Darwinian evolution and concentrates upon biodiversity, the American Museum of Natural History emphasizes taxonomic order, The Natural History Museum in London focuses upon Darwinian principles, and the display designers of the Field Museum in Chicago utilize images to show evolution as a random process (Asma, 2001).

### Introducing, Demonstrating, and Reinforcing Concepts with Imposed Images

The most familiar use of images in science education is to assist in introduction of new concepts, to demonstrate concepts as they are introduced, and to reinforce previously introduced concepts. Within biology, for example, life-cycle diagrams are invaluable, especially in the case of unfamiliar and/or microscopic organisms, including many parasites and microbial eukaryotes such as cellular slime molds (Bozzone, 1997). Skilled line drawings of unfamiliar organisms are also in frequent use. For example, Hershey (1999) incorporated a variety of line drawings from botany texts dating from 1896 to 1988 to introduce the little known parasitic and saprophytic plants into a food chain unit within a non-majors college biology course. Photographic were utilized by Lundstrom (1999) to detail the effect of the fungus *Castanea dentate* (Chestnut Blight) on the American Chestnut Tree, as an introduction to the genetics of both the tree and the fungus, the evolutionary response of the fungus to chemicals, and reflections upon the cultural impact of the demise of a once widespread and important tree in the eastern United States. Lundstrom notes that a single image can be used to introduce many topics within forestry, ecology, introduced species, parasite-host relationships, genetics, recovery and succession, and evolution.

Eshel, (1997) describes construction of a demonstration of water movement among soil particles, to be rather ingeniously displayed as an image on an overhead projector, which demonstrates basic processes of soil-water physics operating at both the microscopic and molecular levels, and are relevant to studies of ecology, plant physiology and agriculture. Eshel's image/demonstration – placed on an overhead so that all students and the teacher make observations simultaneously, thus aiding explanation and teacher-student interaction – is used to teach concepts such as matric water potential, diffusion path tortuosity, and void space partitioning between gas and liquid phases, without the necessity for full mathematical formulation of these concepts, which would be beyond the capabilities of many novices. Here an image aids visualization of important processes, and bypasses the confusion engendered by a theoretical approach.

Images served as reinforcement in an interdisciplinary environmental science course for non-majors (“The Individual, Science, and the Environment”) at Bradford College, MA, where the primary objective was to facilitate and stimulate scientific literacy (Adams et al., 1989). One assignment reported as especially useful by Adams asked that students find images in newspapers and periodicals that would establish the current and important nature (relevance) of topics previously discussed in class.

Images also serve as data sources for inquiry activities, and as tools for carrying out these activities. Kinematic studies are an excellent example, where a series of photographic images of an animal in motion have been used to quantify factors such as velocity, frequency of oscillation, joint angle, or foot placement (Seveyka et al., 2000). Seveyka points out that exercises utilizing images as data sources “provide opportunities for students to sharpen observation skills, develop questions, test hypotheses that relate animal motion to the design, size, behavior and ecology of

an animal”(p.143). In addition to obvious areas of exploration such as characteristic flight patterns in birds, Seveyka’s students performed prey capture studies from image-based data. Pecking motion in woodpeckers provides an excellent example: student analysis of photographs of the beginning and end of a peck revealed that this capture motion followed an arc rather than a straight line. Images of dinosaur footprints provide a source upon which students base calculations of leg length, stride length, and walking and running speeds of dinosaurs, and finally compare these to those of birds and a variety of mammals (Caton & Otts, 1999), an activity that allows middle and high school students to experience how scientific knowledge may be constructed by indirect means.

Images may also function instrumentally in inquiry activities by providing information relating to the solution of problems, as in illustrated manuals and field guides. A comprehensive guide to microorganisms usable at the junior high school level contains photographs and line drawings of more a hundred commonly encountered micro-animals, micro-fungi, protists, and monerans commonly encountered by students (Rainis & Russell, 1996), allowing students to identify these organisms without extensive knowledge of taxonomy and nomenclature. Images showing morphological features can be used to teach data collection skills: Schlessman (1997) uses of diagrams of floral morphology to teach students how to make morphometric measurements as part of a data collection to evaluate competing evolutionary hypotheses concerning the relationship between variation in floral structure and variation in kinds and behaviors of pollinators.

Scientific illustrations also serve to illuminate the nature of science (McComas, 1997) and demonstrate the interconnectedness of areas of knowledge (Dunn, 1990; Flannery, 1999b; Kangas, 1998). Studying original sketches with their associated field notes may add depth to

understanding of the nature and history of science. As an example, McComas (1997) points out that an examination of Darwin's field notebooks, complete with sketches, permits a greater understanding of the original data and the observations which guided Darwin's thinking as he pieced together the truism that species do change, and the mechanism by which these changes occur, than does the mythologized accounts of the finches and tortoises found in most textbooks. Dunn (1990) emphasizes the use of images that show or imply 'where' organisms or phenomena occur, thus linking biology and geography - important because college students' knowledge of geography, especially outside the United States, is frequently deficient.

A fertile area of exploration where images may demonstrate links between areas of knowledge is that of the art- science interaction. Flannery (1999b) comments that artist reconstructions of dinosaurs from assorted items of scientific knowledge offer compelling examples of this connection, and also demonstrate the inferential nature of paleontology. An entire unit of exercises developed by Kangas (1998) explores the links between art and ecology. Kangas emphasizes that art is essentially modeling, which is also a crucial component of ecology – a model being a simplification of reality created to communicate specific information (i.e., not all of the detail of reality is included). As a composition, each work of art has both form and content that is manipulated by the artist with a particular style (Stechow, 1953, p.20). Kangas (1998) recommends discussing these terms in class, and attempting to show how to separate form and content. The remaining teaching exercises are divided into two categories; the ecological content of paintings and the artistic form of ecological models.

With respect to ecological content, Kangas distributes a collection of images of ecosystems (such as the tropical forest), and asks the students to evaluate their ecological content in terms of ecological concepts, particularly the diversity of organisms (animals) shown, and the

matching of animals with their habitats. The ecological content is then critiqued in class discussion. For example, many paintings show an unrealistic diversity of organisms, each of which is unusually exposed and indicating little interspecific interactions (the 'Peaceable Kingdom' fallacy - Gould, 1989, p.347), but Kangas takes care that students understand inadequate ecology is not necessarily poor art. Art is like modeling in that the scene need not represent reality, but merely represents the artist's intentions. Kangas then exposes students to 'good' ecological art, such as a poster series created by Charles Harper for the National Park Service, which include enough individuals of one species and sufficient interactions to almost completely describe an ecosystem, although Kangas comments that even here, species richness remains unnaturally high. By means of such examples, art serves as visual reinforcement of previously learned concepts, and also invites critical thinking. When illustrations are sufficiently detailed, Kangas finds it possible for students to calculate diversity indices or draw trophic pyramids for the species included.

Symbolic diagrams are frequently used as models of ecosystem, and contain several different kinds of information. The individual symbols have specific meaning in terms of what they represent in the ecosystems, and the connections illustrate pathways of cause and effect, and networks of influence. There is also information content in the relative abundance of symbols used to make the diagram. Form is difficult to define, but an important quality in judging an image, including the elements of balance, contrast, rhythm, and variety (Dewey, 1934/1984), and serving as a mode of communication or expression. Kangas suggests that diagrams representing ecological model have their own form that can be analyzed: e.g., Lindeman's (1941) model of the energy flow in an ecosystem has a closed, circular form with pathways flowing around the diagram and converging into the central, smaller circle of bacteria and ooze. Although

pathways flow in many directions, the form of the diagram emphasizes the convergence of pathways to bacteria and ooze at the center. Diagrams can likewise be analyzed for how they embody hierarchical information, such as that of trophic levels making up an ecosystem that is merely a single component at the landscape level, and Kangas suggests a class exercise in which students evaluate a ‘gallery’ of ecological diagrams as good or poor art

Given the potential of images in science education, some educators employ exercises specifically designed to improve observation skills and visual literacy, with the aim of systematically teaching students to identify significant elements within a scientific illustration. Recognizing that object visualization skills are positively correlated with the performance of students in physics, biology, chemistry, and the geosciences (Siemankowski & MacKnight, 1973), Melinda Small and Mary Morton (1983) introduced a spatial visualization training component into an organic chemistry course at Bowdoin College. The visualization training systematically taught students to read two-dimensional notation, imagine three-dimensional models, carry out operations on these imaginary models, and make judgments about the results of the imaginary manipulations. Students receiving this instruction received significantly higher scores on questions in their final exam that contained components requiring visualization than did a control group.

#### Use of Induced Images in Inquiry-Based Science Activities

Many inquiry-based science classes are suited to the construction of images by students, reinforcing their understanding of concepts, enabling the recognition of patterns in data that are not self-evident, and demonstrating experimental results and resultant understanding to the instructor and others. The usefulness of induced images is not limited to the laboratory, however - diagramming lectures in such a way that connections between concepts are clearly stated, as



occurs with concept mapping, is a technique frequently recommended to students by instructors (e.g., Ambron, 1988).

Image construction by students frequently serves the dual purpose of reinforcing understanding and forming a basis for assessment. In a literature review and poster presentation assignment designed to stimulate interest in science and teach aspects of the nature of science, undergraduates selected images to illustrate or reinforce a point, as they investigated the current understanding of cellular and molecular aspects of a human disease (Mulnix & Penhale, 1997). The research of students in an independent study seminar at the University of Wisconsin was assessed on the basis of graphics produced for public instruction at the Milwaukee zoo (Sauro & Elsen, 1988)

The learning potential of laboratory exercises shows evidence of increasing with the incorporation of induced images, or at the very least, the visual documentation of student observations. Mills et al. (2001) required that undergraduate microbiology students document their observations through a microscope with a digital camera, which enabled an increase in discussion among the class when such images were projected onto a screen, and served as an aid in confirming identifications and in assessment. Construction of a meaningful image was found to improve student understanding of the DNA molecule in an introductory college biology laboratory (Williamson & Campbell, 1997). The students collected data from electrophoresis to derive a restriction map of a bacterial plasmid, an exercise that also aided understanding of one of the goals of the Human Genome Project - to establish restriction maps) to serve as genetic road maps to be used in more detailed molecular analyses.

Other educators have targeted the knowledge gains that follow from an increase in perceptual skills as image making is incorporated into science classes. Todd (1988) found that

incorporating visual arts into geology increases student perceptual skills and ultimately resulted in significant gains in knowledge, compared to a 'straight' geology course lacking in this interdisciplinary component, and also increased the degree of student engagement with the material. Students were assigned to take photographs and make drawings of geologic phenomena to this end, and a member of the art faculty accompanied the field trips, with the express purpose of encouraging students to learn to see.

In an ambitious and involved attempt to learn ecology visually, students in a Field Natural History course at Sweet Briar College produced video documentaries on local natural history subjects (Fink, 1997), such as the succession of organisms feeding upon road kill, the diversity of organisms occupying dead trees, and medicinal plants. Fink reports that this project is suitable for non-majors and lower-level undergraduates who are not ready for quantitative work, have little experience with field biology, but are enticed by and perform well in substantive independent projects. The course is intended to develop the three traits Fink considers essential to a scientifically oriented naturalist; skill at seeing patterns in nature and framing interesting questions about these patterns, knowledge of the local biota, and an understanding of ecology, evolution, and behavior sufficient to organize their observations within a theoretical framework. She reports that one great advantage of video cameras over field notebooks is that novice naturalists do not record enough observations, and do not record them in sufficient detail to be useful. The video allows reinterpretation of observations at leisure as the naturalists gain experience, with the aid of the instructor as necessary. There is much emphasis upon editing as the students gain skill in judging the information content of their images, and the films are graded upon content and clarity, and frequently incorporate drawings and diagrams by the filmmakers, as they become more competent naturalists. Fink notes that as confidence grows,

the students pay increasing attention to a wider spectrum of characteristics and phenomena, and also display the curiosity, persistence, and ingenuity characteristic of committed naturalists, developing lines of questioning that are derived from original observations rather than reading.

### Combining the Use of Imposed and Induced Images

Inquiry-based science classes frequently utilize both pre-existing images to introduce concepts or support activities and student construction of images to reinforce concepts, provide data sources, and demonstrate understanding. This approach to laboratory activities is exemplified in a workshop that has been regularly presented at the annual meeting of the *National Association of Biology Teachers* since 1995, in which participants are instructed in both creation and analysis of anatomical and physiological images. Imaging techniques include data collection using scanners, video cameras and digital cameras, and enhancement of biomedical images to reveal hidden details. Analysis techniques allow students to make precise and complex measurements, and include controlled animation of time-lapse images, analysis of DNA profile images to determine fragment length and to answer evolutionary and ecological questions, and measurement of microscopic structures in light and electron micrographs.

A combination of the use of imposed and induced images is particularly suited for the field component of science courses, where students learn from images as they prepare for and practice field work, then ultimately create their own images. Ohkawa (2000) used visual images of plant characters in a key developed for assisting novices in field identification, and recommends this technique for other areas of biological identification. As students encountered plants in the field, these visual characteristics could be added to or changed, and when the key did not cover a given plant, students constructed their own list of visual characters and

incorporated this into the key. Here, the students were able to construct knowledge visually after developing their content knowledge using the image-based key.

Another plant-centered field experience involving image use by high school students is described by Bunderson and Cooper (1997). A group of select Utah secondary students produced a comprehensive plant list and photographic images of species occurring around a small stream flowing through the floor of a remote canyon, and the image collection was later used in the classroom by students unable to participate in this necessarily restricted trip. Thomasson (2002) describes adding to the value of botanical and ecological field trips by having students capture digital images of fungi in the field, then utilizing these images for further investigation of the organisms in the lab. This integration of image use with fieldwork helped the students to develop their observation skills and increase their understanding at leisure, and the instructor also used the images in assessment.

Images may be considered a valuable tool by the instructor, yet meet initial resistance from students. In an interdisciplinary course designed to introduce topics in geology, biology, chemistry, physics, and math via the study of speleology, Fawley (1981) placed early emphasis on the study and interpretation of topographic maps, an exercise at which students initially balked yet became enthusiastic about as their visual understanding increased. Fawley reports that many geologic concepts became firmly entrenched in student understanding when this exercise was extended to having students produce topographic maps of their own, which was assigned later in the course - after geologic features had been studied individually (also by extensive use of images) to aid map interpretation. Fawley found that the use of images of features, and extensive visual interpretation and expository exercises with the maps both established interest

and stimulated the desire for additional information, and also resulted in the students being competent and knowledgeable when they were later introduced to field work in caves

Student benefit from the use of images in the science classroom is to some extent proportional to their degree of visual literacy (Blystone & Dettling, 1990). One exercise described by Willoughby (1991) uses images to clarify resolution and magnification, two concepts that are often confused by students. Willoughby's exercise involves reproduction of a pre-existing drawing, where the reproduced image is variously constructed using grid paper, subdivided into 4, 16, and 64 squares and another paper where the grid is only a blank square. Each student constructs one images and exchanges with another student, whereupon the reproduced image is interpreted and a decision is made about what the original actually looks like. The exercise forces student reflection about how an image is actually made, and a suggested follow-up is to have the students then look at maps, photographs, and diagrams, and decide if these are of high or low resolution, and make judgments about the amount of information actually presented. Thus the students are introduced to the Tuftean criterion of maximizing data-ink (Tufte, 1983).

#### Summary: Seven Major Functions of Images in the Science Class

The preceding examples of the effective utilization of images in a variety of science classes suggest how ornithological illustrations might function in inquiry-oriented ecology education. Seven major areas of application seem to emerge:

1. To increase student engagement with material prior to field experiences and laboratory experiences, particularly important at the stage when useful inquiry questions are being developed (e.g., Brooks, 1985; Dubeck, 1981; Fawley, 1981; Leonard et al., 1996).

2. To provide cognitive scaffolding as concepts are introduced, demonstrated, and reinforced.( e.g., Adams et al., 1989; Bozzone, 1997; Eshel, 1997; Hershey, 1999; Kangas, 1998; Leonard et al., 1996; Lundstrom, 1999; Mulnx & Penhale, 1997; Williamson & Campbell, 1997; see also Asma, 2001).
3. To substitute for field experiences in cases of logistical difficulty (such as exotic locales) and to support laboratory experiences when organisms are unavailable, or cannot easily be viewed or captured (e.g., Bunderson & Cooper, 1997; Flannery, 1998b; Thomasson, 2002).
4. To provide data sources for activities, and as tools to assist problem solving (e.g., Caton & Otts, 1999; Fawley, 1981; Ohkawa, 2000; Rainis & Russell, 1996; Seveyka et al., 2002; Schlessman, 1997; Thomasson, 2002).
5. To assist in development of visual literacy and field observation skills (e.g., Fawley, 1981; Fink, 1997; Small and Morton, 1983; Todd, 1988; Willoughby, 1991).
6. To illustrate the nature of science and the interconnectedness of various areas of knowledge (e.g., Asma, 2001; Caton & Otts, 1999; Dunn, 1990; Flannery, 1999b Kangas, 1998; Lundstrom, 1999; McComas, 1997).
7. To allow students to demonstrate results, support their arguments, and to provide instructors with material for assessment (e.g., Chowning, 2002; Fink, 1997; Mills et al., 2001; Mulnx & Penhale, 1997; Sauro & Elsen, 1988; Williamson & Campbell, 1997; see also Wandersee, 2000).

#### Relevance of Reviewed Literature to the Purpose of This Study

A wide range of topics drawn from the sociology of science, the history and practice of art, philosophy of vision, graphic design theory, and the goals and methods of educational practice has been discussed in the preceding review. It is appropriate to conclude this section by linking

these areas to the research objectives of the study: to explore how and why ornithological images as a representative subset of scientific illustrations might contribute to the teaching of ecology, and also how the life-development and professional practice of ornithological artists, as a representative subset of ecological scientists or naturalists, might likewise inform the direction of education in ecology.

The characteristics of scientists – in particular the characteristics, life-stories, world-view, and practices of scientists of the ‘naturalist’ persuasion – has potential relevance for identification of those students who are likely future ecologists, and for assisting personal and professional development of such individuals. Observation skill, and the development of expert perception of the natural world is a primary skill of ecologists, and thus the nature, development, and limits of visual skill and understanding have been reviewed here, along with the general nature of the development of expertise.

The history of ornithological illustration and the types of image available to the educator provides necessary background when considering how and when to utilize such images in a formal or informal educational setting. Similarly, the extensive exposition of Edward Tufte’s (1983; 1990; 1997) theories concerning excellence in scientific graphics details a useful set of criteria for selection of such images.

Finally, this chapter considered general aspects of the classroom use of scientific imagery, with special reference to the use of natural history illustration. The necessity for the development of visual literacy in the student audience is stressed, in order that maximum benefit might be obtained from an ecology curriculum incorporating extensive imagery. The perspectives of national and international authorities on the goals of education in environmental science and ecology were reviewed, and the most important concepts in ecology generally

identified by these experts were discussed. At a more specific level, the many ways in which images have been used by a variety of expert science educators were explored, and the specific functions that an illustration can perform within a classroom setting were identified.



### CHAPTER 3: RESEARCH DESIGN AND METHODS

This study explored the life-histories, practices, and products of selected ornithological artists, with the intention of elucidating the relevance of all of these to biology education. The first subquestion addressed was the broadest and most general, asking what the life-stories of selected contemporary artists may have in common – and also where they are unique - with an eye to identifying the experiences, conditions, and factors associated with the development of expertise in both the visual arts and ornithology. The general and exploratory nature of this question implied that the answer would necessarily require extensive description of the individual artists, and the people, institutions, traditions, and events that played a role in shaping their lives. No a priori theoretical lens was employed in this first portion of the study; which was designed simply to uncover information about the artists' lives, experiences, and beliefs, and to identify those events and influences that appear to be of common significance throughout the group of participants, and those that any given individual within my sample believed to be significant.

The second subquestion examined whether a common worldview (or set of values) of the naturalist, as posited by Janovy (1985/1996) exists among this group of ornithological illustrators, and asked if the direction of their lives was driven by an unusual degree of inherent biophilia (Wilson, 1984) and/or possession of a 'naturalist intelligence' (Gardner, 1999). In particular, I attempted to ascertain if the naturalist intelligence, as described explicitly by Gardner (1999) and implied by the works of others (Kellert, 1993; Wilson, 1984; Keller, 1983; Eisely, 1964) was evidenced by the self-descriptions of these individuals, or if their particular combinations of interests and abilities sprang from a composite of other intelligences, such as scientific and artist abilities. If the 'naturalist intelligence' showed evidence of being a real

phenomenon in these illustrators, I planned to examine its characteristic developmental history, from a raw potential to that developed state evident in a professional ornithological illustrator. A description of the values and worldview common to these naturalist-illustrators was attempted, along with an inquiry into the age and stage of life at which the naturalist intelligence appeared to manifest, and an exploration of the factors that support and nurture this orientation to the extent that the study of natural history becomes a life's work and consuming passion.

Given that these questions are emergent in nature, aiming to uncover themes and relationships within the disposition, practices, and worldview of ornithological illustrators, a qualitative approach to this part of the study was appropriate (Biddle & Anderson, 1986). A multiple case study approach, where the case is here defined as 'selected contemporary ornithological illustrators' was chosen on the grounds that this is amenable to uncovering both uniqueness and commonalities in the lives and practice of these individuals (Stake, 1995). Typically, multiple case studies have embedded within them methodology from a variety of qualitative traditions, such as biography, phenomenology, and ethnography (Cresswell, 1998). Within this case study, I utilized a method of interpretive biography, described by Denzin (1989) as the "studied use and collection of life documents that describe turning-point moments in an individual's life" (p.69). The very specific approach I chose was that of the oral history interview, which has the declared goal of "understanding the complex world of lived experience from the point of view of those who live in it" (Schwandt, 1994, p. 118).

Not only is oral history an established method of documenting intellectual history (and the history of medical science in particular) but oral evidence has special value in studies such as this where the researcher is primarily concerned with the process of work (Thompson, 2000). Unstructured interviews may reveal "the experience of work, and the social relationships and

culture which follow from it” (p.91). Thus the use of unstructured or loosely structured interviews here within a multiple case study combined to provide a picture of the rewards, frustrations, motivations, and challenges of the world of ornithological illustrators, in addition to revealing the personal lived experience of the individual artists. The use of other data sources, such as paintings, reviews, and biographical materials was considered to corroborate these self-descriptions and constructions of the world of contemporary bird illustrators, but given that this is a small, esoteric, and relatively unexplored field, the words of the participants comprised the primary data source.

#### Selection of Ornithological Illustrators for the Study

Eight established bird illustrators were selected for study. Inclusion of an illustrator in the study was subject to the criterion that the individual had been a major contributor to at least one published field guide to birds. Second to this, the sample was based upon accessibility, meaning that the artist agreed to participate and could grant sufficient time for the interview. The following categories were established with respect to the developmental stage of the career of the participants:

1. Gurus – implying the artist is a recognized leader in the field, and has influenced the domain to some degree
2. Mid-career artists – implying that the artist has been sole author and/or illustrator of at least one published field guide.
3. Rising stars – younger artists who have contributed individual plates to technical publications and field guides.

Of the eight ornithological illustrators interviewed in this study, three had attained “Guru” status, three were “Mid-career artists” and two were classified as “Rising stars”. John O’Neill,

Douglas H. Pratt, and Larry McQueen qualify as “gurus.” All three illustrators have illustrated and edited several field guides, and are accomplished narrative painters. O’Neill and Pratt have also authored texts and technical publications, and McQueen’s work has been influential in the public sphere in that it has been popularized as posters for birding and conservation organizations.

John O’Neill has influenced the ornithological world as both scientist and artist. O’Neill has discovered 13 new species of Peruvian birds during his many expeditions to that region, served as the director of the Museum of Natural Science at LSU for several years, and has authored technical articles in such leading journals as *The Auk* and *Biological Conservation*. He has contributed plates to *The National Geographic Society Field Guide to the Birds of North America* (National Geographic Society, 2002), *A guide to the Birds of Trinidad and Tobago* (French, 1991), *Birds of Brazil* (Sick, 1993), and the *Reader’s Digest Book of North American Birds* (1990). He is also the author and illustrator of *Great Texas Birds* (O’Neill, 1999) and currently the coauthor and art director of *Birds of Peru*, to be published by Princeton University Press, a book that will be distinguished by inclusion of more color plates than any previously published bird guide. His paintings have been featured on three covers of *Science*, in the *Auk*, and in *Audubon*, and *National Geographic* magazines, and are in the permanent collections of the Houston Museum of Natural Science, The Beijing Natural History Museum, and the Denver Museum of Natural History.

Douglas H. Pratt is a former colleague of O’Neill at the LSU Museum of Natural History. Also a distinguished ornithologist in his own right, Pratt’s interests focus upon the birds and natural history of the Hawaiian Islands and Micronesia. In addition to the contribution of numerous scientific articles to journals such as *The Wilson Bulletin* and *The Condor*, Pratt has

coauthored and illustrated *A Field Guide to the Birds of Tropical Hawaii and the Tropical Pacific* (Pratt et al, 1987), and is sole author and illustrator of a monograph *The Hawaiian Honeycreepers: Drepanidinae* (Pratt, 2005), a group of birds on which Pratt is considered to be the world's leading authority. Pratt has also contributed illustrations to many other ornithological guides, including *The Birds of Northern Melanesia: Speciation, Ecology, and Biogeography* (Mayr & Diamond, 2002), *Birds of Kenya and Northern Tanzania* (Zimmerman et al., 1999), *Enjoying Birds in Hawaii* (Pratt, 2002), *Hawaii's Beautiful Birds* (Pratt, 1996), and *Birds of Colonial Williamsburg* (Feduccia, 1989). Pratt is also an accomplished narrative painter, and has produced a number of commissioned paintings for private clients.

Larry McQueen's work is widely known throughout the scientific, birding, and artistic communities. A former conservation biologist and graphic designer, he has made substantial artistic contributions to many field guides, including *The Audubon Master Guide to Birding* (Farrand, 1983), the American Bird Conservancy field guide *All the Birds of North America* (Griggs, 1997) the *Birds of Venezuela* (Hilty, 2003) and the *Birds of South East Asia* (Ripley et al., 1976/2005). Most recently, McQueen has been a contributor to, and served as an art editor of, the *Birds of Peru* (Schulenberg, Stotz, & O'Neill, 2005). In addition to technical illustration, McQueen's narrative painting has appeared widely in calendars, catalogs, and magazines – he is a regular contributor to the Cornell Laboratory of Ornithology publication *The Living Bird* and has produced a number of posters on behalf of bird conservation organizations.

The merit of Larry McQueen's narrative painting has been recognized outside the ornithological and conservation communities: his work has been selected for the prestigious Leigh Yawkey Woodson "Birds In Art" exhibit nearly every year since 1979, and he was named Audubon Alliance Artist of the Year for 1993 Audubon Alliance Artist of the Year for 1993. He

is also advisor to the Eckelberry Endowment administered by the Academy of Natural Sciences, which offers mentoring support to painters, sculptors, printmakers and other artists wishing to better acquaint themselves with the natural world through both museum and field research. All three illustrators are also accomplished narrative painters, and McQueen has now decided to retire from producing field guide plates and pursue the narrative genre exclusively.

Sophie Webb, James Coe, and Eustace Barnes have each co-authored and illustrated at least one field guide, and are thus classified as mid-career artists. All are prolific painters. Webb coauthored and illustrated *A Guide to the Birds of Mexico and North Central America* (Howell & Webb, 1995), has written and illustrated two award winning children's books about seabirds (*Looking for Seabirds*, (Webb, 2004); *My Season with Penguins*, (Webb, 2000), and has contributed plates to *The Birds of Peru* (Schulenberg, Stotz, & O'Neill, 2005).

Eustace Barnes coauthored and illustrated *Pigeons and Doves* (Gibbs, Barnes, & Cox, 2001) has an extensive knowledge of the birds of the South American rainforests as a result of a many years of experience as a tour guide in that region, and is the illustrator of *A Field Guide to the Birds of Peru* (Clements & Shany, 2001) and *The Bowerbirds: Ptilionorhynchidae* (Frith & Oxford, 2004). James Coe is the sole author and illustrator of the Golden Field Guide *Eastern Birds* (2001), and has contributed illustrations to the MacMillan Guide *Birds of North America: Western Region* (Bull, 1990), *Birds of New Guinea* (Beehler, Pratt, & Zimmerman, 1986), and a widely used college textbook, *Ornithology* (Gill, 1995). Coe's artwork has also appeared on the covers of leading ornithological journals (*The Auk* and the *Wilson Bulletin*) and the popular bird watching magazine *Birdwatchers Digest*. In recent years, Coe has become a recognized narrative painter, and is a leading contemporary proponent of plein air landscape painting.

The two ‘rising stars’ of this study are Daniel Lane and Bill Strausberger. Dan Lane has already made a number of contributions to the field, and only qualifies for this classification due to his youth. Lane is the youngest of the artists participating in this study, age thirty at the time of his first interview with me in 2003. Lane has illustrated and co-authored many technical publications, and has contributed a number of covers to the leading ornithological journal, *The Auk*. He has illustrated the birding sections of a number of eco-travel guides to South American countries, and has contributed a number of plates to the forthcoming *Birds of Peru* (Schulenberg, Stotz, & O'Neill, 2005). Holding a master's degree from Louisiana State University's Museum of Natural Science, Lane divides his time between serving as a research associate at the museum, and as a bird tour leader in South America. Lane has accompanied many expeditions to Bolivia and Peru, and made ornithological news in 1996 when he discovered the Scarlet-banded Barber and again in 2004, when he discovered a new species (and possibly a new genus) of tanager in the Peruvian cloud forest.

Bill Strausberger, also in his early thirties, is a recognized ornithologist and lifetime amateur bird painter, but is relatively new to the field of technical illustration. Strausberger received his Ph.D. in ornithology from the University of Illinois in 2001, and is currently a researcher at the Field Museum of Chicago. He has been selling his narrative paintings since his high school years, has illustrated technical papers, and produced two covers for *The Wilson Bulletin*. As his ornithological career develops, Strausberger intends to enter the area of field guide illustration. Strausberger is of interest to this study for two reasons: his long-time interest in birds, reflected in his artwork, is in the ecology of bird behavior rather than morphology and systematics, and he is a relative outsider to the close-knit bird art community. Whereas the

ornithological community and bird-loving public alike recognize the merit of his work, at this time he remains a relative newcomer to the bird art community.

### The Interview Process

Approximately three hours of interviewing was conducted with each of the eight artists. Interview formats within educational research vary from a structured format resembling an oral survey, where very specific questions are presented in a specified order, to those which are totally unstructured and encourage the interviewee to simply ‘tell his story’ in any manner he or she sees fit, with minimal interviewer direction (Ives, 1995). I desired to keep the structure of these interviews minimal, in order to elucidate those aspects of the life-history that the artist perceived as significant rather than pursuing my own pre-conceived notions of a ornithological illustrators life experiences, while at the same time addressing a number of factual issues and philosophical questions that I consider represented necessary biographical data. Thus I prepared a sample protocol (Appendix E), listing specific questions, some of which served to ‘warm up’ the respondent during the difficult first minutes of the interview, and inserted the remainder during gaps in the conversation, or when the artist spontaneously approached a specific topic. For example, I was interested, for example, in the reconciliation of the aims of art and science, and by extension, whether each ornithological illustrator considered himself or herself as primarily an artist or scientist. This angle was suggested by an early formal question in which I would ask the artist to describe his or her occupation, and followed up on later at natural points in the conversation. In an earlier pilot study with visual artists in the Baton Rouge community, I found that philosophical questions, or those relating to personal issues such as self-concept, were best approached obliquely when the artist was effectively musing along related lines. Introducing complex or personal questions too early in the interview process, or too abruptly, tended to



produce stilted and limited responses, forcing the interviewer to beat a hasty retreat to a more neutral topic.

Times and places for interviews were arranged at the artists' convenience. All but one artist (Bill Strausberger) are essentially self-employed and necessarily protective of their time and energy. Where I would have ideally liked to conduct the interviews at the artists' studios, this was not encouraged at the first interview by the locally based artists, and thus interviews with John O'Neill, Doug Pratt, and Dan Lane took place at the LSU Museum of Natural Science, a familiar work environment to all three individuals, and one which provided a sense of familiarity and comfort for the interview. Eustace Barnes and Bill Strausberger were interviewed in their hotel rooms during the 2003 meeting of the American Ornithological Union in New Orleans. James Coe suggested the initial interview take place by telephone, and that we could meet in his home territory of New York state in the future if I felt the telephone format of the interview was unsatisfactory, or wished to follow up. The interview with Sophie Webb took place over two days at her home in Salinas, California. Larry McQueen lives in Eugene, Oregon and was the most difficult of the artists to schedule for an interview. After intermittently corresponding for a year, we eventually met one afternoon at the LSU Museum of Natural Science while Mr. McQueen was working with the Neotropical bird collections there for his contributions to the *Birds of Peru*. Some basis for trust became established during this first series of interviews, and all artists agreed to participate in follow-up interviews, answering further questions by e-mail, telephone, or allowing me to personally visit their homes or studios.

Each interview was tape-recorded, and the participants all signed consent forms (Appendix A) describing the study as required by the Institutional Review Board for Research with Human Subjects. During the course of scheduling the interviews, I informed the participants

that the nature of my interest in the interview lay in tracing the course of a life that successfully combined expertise in art and science, and the personal characteristics and philosophies of those that had achieved this distinction. All participants also signed releases permitting the audio taped interviews to be retained in the archives of the Harry T. Williams Oral History Center at LSU.

Interviewing attentively, and truly listening and responding to nuances of the conversation and the respondent's demeanor is a demanding and intense experience. It is recommended by experts that the interviewer immediately engage in writing up 'field notes' describing the aspects of the experience not amenable to audio recording, and also committing to paper those post-interview thoughts, new questions, and impressions that arose (Bogden & Biklen, 1998; Ives, 1995). This is a valuable suggestion and one that I personally extended: I found myself to be intensely preoccupied with the interview for some time after the thanks and goodbyes had been exchanged, and formed the habit of carrying around a journal centered upon each artist, in which I would record musings and impressions for at least a week, finding that I could not process the entire experience immediately following the interview.

### Analysis

One ethical stumbling block for the qualitative researcher is subjectivity, and I am sharply aware that my personal passion for the biographies of eminent naturalists, in particular those of independent and idiosyncratic disposition, is a bias to which I must remain alert as the interview transcripts are examined for pattern and meaning. Tempted though I am to relate these life-stories in a thickly descriptive narrative form, the issue must be addressed of moving from story to scholarship (Josselson, 1993) or of transforming "story material from the journalistic or literary to the academic and theoretically enriching" (p.xi; see also Spence, 1982). Interpretation is the very particular strength of qualitative research, allowing questions to be raised rather "put

...forever to rest” (Wolcott, 1995, p.26), and the interpretations I propose to offer of significant aspects of these artists lives may not be at my sole discretion but must be rooted in systematic analysis.

The proposed analytic procedure is to code the individual interview transcripts, with respect to perspectives held by the artists, ways that the artists think about art and science, life and career passages, significant events, and work habits (Bogdan & Biklen, 1998). A pilot study of the transcript of one John O’Neill interview resulted in the emergence of 32 initial coding categories, including observation skills, artistic influences, mentors, community of bird artists, teaching, concern with the ‘jizz’, conflicts between art and science, self-perception as scientist, self-perception as artist, concern with personal autonomy, and concern with scientific integrity. As the remaining transcripts were examined, codes were discarded and reformulated until a list common to all transcripts and reflecting recurring themes throughout all eight interviews was obtained (Strauss & Corbin, 1990).

Given the general and exploratory nature of this question, and due to the highly unstructured format of the interviews where participants were encouraged to talk at length about their particular interests and individual perspectives, I have elected not to attempt a quantitative content analysis of the transcripts, where frequency counts of the occurrence of each coding category are performed (see Gall & Borg, 1996). I preferred to utilize the approach of Stake (1995) for extraction of meaning from case studies, where emergent patterns of regularities in the codes for each transcript were allowed to emerge and thus identify themes of significance in the life of each bird artist. This initial within-case analysis will identify people, places, ideas, and events of significance in the artist’s life and practice. I had planned for, further interviews to take place for clarification and/or further exploration as new questions developed, but these proved

unnecessary. With the exception of a few e-mail enquiries to clarify names and places, the initial interview transcripts provided sufficient material for the study.

Since comparison with another appropriate case offers the qualitative researcher a means of control (Wolcott, 1994), a between -case analysis of themes and categories was conducted across the entire set of interviews. This procedure enabled the interpretive construction of a composite picture of significant common themes in the lives of contemporary bird illustrators, while the within case analyses highlighted where these individuals are unique in their experiences, values, and practices.

The approach to the second subquestion, that of evidence for the existences of the naturalist intelligence, and the path of its development, also employed a similar within and cross-case analysis of the same transcripts. The use of different coding schemes upon identical materials when the research has a different purpose is well-established in qualitative research (Bogdan & Biklen, 1998) For this subquestion, I employed a specific theoretical lens – that of inherent biophilia and the naturalist intelligence - as I approach the transcripts in a less open and more purposeful manner during the coding procedure, searching specifically for instances of the naturalist intelligence, and events that appear to relate to its development. With transcripts coded for relevant passages, I again developed a set of themes related to the issues of the naturalist intelligence for each artist. I anticipated that a cross-case analysis of themes here may reveal some common attributes that might be said to represent the ‘raw’ naturalist intelligence, and also some common elements relating to its development and expression. The naturalist intelligence, as conceived by Howard Gardner (1999), is posited to have a developmental trajectory from the raw potential to that of expert, but stages of and influences upon this trajectory have not been described. Multiple case studies such as this have been widely used in the inductive construction

of theory (Merriam, 1988), and my ultimate goal in this cross-case analysis was to generate a substantive theory that explores and describes the development of the naturalist intelligence.

### Validity and Reliability of the Analysis

Coding of the transcripts, and interpretation of the analysis was checked for reliability by two independent reviewers (see Appendix F), with experience in analysis of oral history narrative. The reviewers were given portions of the transcripts from which each theme was developed, and were asked to indicate their degree of agreement on a 1 – 10 scale (10 being perfect agreement) with the author's analysis. Agreement between the author's analysis and those of the reviewers was subject to an attribute agreement analysis by calculation of the Fleiss' Kappa statistic (Siegel & Castellan, 1988). If kappa = 1, perfect agreement between the reviewers and the author would be indicated. If kappa = 0, the agreement would be that expected by chance. In general, kappa values of less than 0.7 indicate that the degree of agreement is unacceptable and kappa values of above 0.9 are considered excellent.

### Examining the Products of Ornithological Illustration: Design Ideals

The third component of this study asked whether ornithological illustrations function as effective scientific graphics, stimulating reasoning processes in the viewer, communicating information efficiently and serving as clear revelations of complex material, as outlined by the graphic design theory of Edward Tufte (1983; 1990; 1997). The two genres of ornithological illustration – narrative painting and technical illustrations characteristic of field-guide plates – were evaluated separately with respect to fulfillment of these criteria. Narrative paintings explicitly serve the purpose of aesthetic entertainment in addition to conveying information, but since many were produced as visual records of new birds, and were painted by artists who were frequently skilled naturalists, it is entirely reasonable to suppose that these works may contain

technical information about their bird subjects, and thus qualify as scientific graphics. Such paintings frequently contain much ecological material within their decorative backgrounds, and these backgrounds may contribute to a fuller appreciation of the ecological context of the species depicted.

Field guide illustrations serve a narrower and more clearly defined purpose, aiming to visually describe the bird sufficiently for field recognition. Since a bird in the field is rarely seen in full view, and is frequently viewed only in flight silhouette, or as a series of partial glimpses as it emerges from vegetation for a few moments, it is desirable that all possible information be included in the field plate, and that this is easily accessible to the eye and mind of the viewer under field conditions. Supplementary information concerning the species' behavior, habitat and distribution is also necessary to reliable identification.

Two rubrics were constructed from Tufte's three-volume theory, and have been specifically designed to evaluate where narrative ornithological painting (see Appendix B) and field guide illustration (see Appendix C) meet Tufte's criteria for effective scientific graphics. With respect to narrative works, the rubric attempted to determine whether the painting satisfied Tufte's two major axioms of maximizing 'data ink' and inclusion of relational aspects of the phenomena portrayed. Thus background elements of narrative paintings should be relevant to identifying or understanding the bird and not be merely decorative, and some ecological context such as behavioral displays, characteristic habitat, or predator-prey relationship should be provided in addition to the portrait of the bird species. The rubric for evaluating narrative work initially evaluated the painting with respect to these axioms, then asked if the actual depiction of the bird is qualitatively and quantitatively 'truthful', thus satisfying Tufte's principles of integrity in scientific graphics. The information resolution of the painting was also evaluated by the

rubric, which dissected exactly how and to what extent the painter had conveyed the multivariate nature of the bird in two dimensions. The final section of the narrative rubric asked if and how the painting serves to stimulate reasoning process in the viewer.

An overlapping, but slightly different format of the rubric was provided for evaluation of field guide illustrations (Appendix C). This different format was justified by the very specific intent of the field guide: to provide detailed information enabling identification of a species under different viewing conditions. Thus compared to the rubric evaluating the narrative genre, relatively more attention was paid to the amount of qualitative and quantitative information provided about each bird species, and the efficiency of access of this information to the eye and mind of the viewer provided by the layout of the plate. Issues of integrity and concealment are also addressed more extensively here, as the avowed purpose of such illustrations is to provide reliable and complete technical information about particular species. Thus it was also considered appropriate to evaluate the field guide plate in terms of any manifest disinformation, defined by Tufte (1997) as the concealment of data that ought to be revealed. The narrative paintings were not be analyzed for disinformation since the painter is not bound by the same intention, and is expected to exercise greater selectivity regarding what he chooses to portray and emphasize. The potential of the field guide plate to stimulate reasoning processes about the bird and its environment was also given consideration. Both rubrics concluded with an overall rating as to the success of the plate or painting in clearly portraying the complex nature of the bird.

#### Sample Characteristics: Narrative Paintings and Field Guide Plates

A review of previous studies indicates that the sample size for analysis of the content and style of images has a lower bound of 40 items (Goins, 2004; see also Abrahamson, (1979), Arango (1995), Ayala (1999), Ziegler (1971). Forty narrative paintings, (two by each of twenty

artists) were selected for evaluation. The choice of paintings was subject to the following criteria and defining characteristics:

1. The painting should be available as an online image in a permanent collection, thus maximizing the use of this study to other researchers and teachers.
2. The painting should include some ecological component in addition to the bird portrait. Since many of the paintings available online in university and museum archives are 'straight' bird portraits, this severely constrained the number and selection of paintings available for evaluation.
3. The sample should represent a broad spectrum of the genre both geographically and temporally. Thus I will included works from the 17<sup>th</sup> through the 20<sup>th</sup> centuries, and include subject matter from as many regions of the world as possible.

Forty groups of plates from popular field guides to birds will were also selected for evaluation and analysis. Since this part of the study had particular interest for teachers, informal educators, and the birding public, I limited the sources of the plates to those contained within four of the currently most popular and respected field guides currently available in North America. The guides selected are *Eastern Birds* (Coe, 2001), *Birds of North America* (National Geographic Society, 2002), *Eastern Birds* (Peterson, 1980), and *The Sibley Guide to Birds* (Sibley, 2001). Each is in wide use, is relatively inexpensive, and easily available to consumers.

Within each guide, birds are described and illustrated by families. I selected ten families of birds that are relatively commonly observed by U.S. birders, and evaluated a plate illustrating each of those families from each of the four guides. The emphasis on more commonly observed birds provided a more representative and cohesive sample, and also provided a contrast to the



study of narrative paintings, since these latter works have a distinct tendency to portray more exotic and unusual specimens.

#### Analysis of the Rubrics: Narrative Paintings and Field Guide Plates

For most items within the rubrics, both closed-format responses and a free response were included. The closed responses permitted summary descriptive statistics to be calculated for each item and for groups of items, while the open responses allowed for construction of a full picture of where and how each genre functions effectively as a scientific graphic.

Data from each closed-format item in the rubric was summarized across all paintings, and this item-by-item summary was repeated for the forty field guide plates. The descriptive statistics summarized the success of narrative paintings and field guide plates in meeting Tuftean criteria. The comments and explanations provided in the free responses to each item were examined in conjunction with the statistics to construct a detailed and specific picture of where and how bird artists have met or failed to meet Tuftean standards of information communication. The two genres of illustration were compared and contrasted, as I examined the specific areas in which each tends to succeed or fail, especially in meeting the challenge of reconciling the objectives of efficiency with that of including relational phenomena.. I also compared the four field guides for their relative adherence to Tufte's ideals. Finally, I considered the questions of whether narrative paintings, which I hypothesize would serve to stimulate reasoning about ecological concepts, also succeeded as sources of technical information, and if field guide plates, which could reasonably be expected to be reliable sources of technical ornithological details, also served to stimulate reasoning about the ecological context of a species.

### Validity and Reliability of the Analyses of Plates and Paintings

Selection of the narrative paintings and plates for analysis was reviewed for suitability of the study by a panel of three expert judges, each of whom is a professional working in the area of illustrated ornithological literature. Each member of the panel reviewed the list of selected paintings and checked a yes/no agreement indicating their opinion concerning the suitability of each painting for the study. The author's evaluations of the artwork (responses to the two rubrics) was also reviewed on an item-by-item basis by the same panel. The Fleiss' kappa statistic was calculated as an indication of agreement between the three judges and the author's selection and analysis of the narrative paintings.

### Investigating the Use of Ornithological Illustrations in Biology Education at the High School and College Level

The review of published lesson ideas and reports undertaken in the review of the biology education literature indicates that scientific images have been used to increase student engagement, to introduce or reinforce content, to substitute for and support lab and field experiences, and to provide data sources for classroom activities. Images have also been utilized to improve visual literacy, sharpen observation skills, and to provide students with data sources to support their arguments. One area that has not been specifically targeted in the science education literature is how images of a particular subspecialty of science – such as ornithology – can be utilized in a classroom setting. In this study, I hypothesized that images of birds have the potential to provide an aesthetic hook to engage the student with science, may inform the ornithology student – in or out of the classroom – about specific morphological, ecological, and behavioral characteristics of specific birds, illustrate the nature of interactions between birds and other organisms, may increase content knowledge and awareness of environmental phenomena, and tangentially provide insight into the perspectives and nature of science. The fourth

subquestion of this study investigated how the classroom teacher might utilize ornithological imagery to provide and/or support ornithological and ecological content knowledge and associated science process skills.

Recommended ecology topics and knowledge of the nature of science is contained within the *National Science Education Standards* (NRC, 1996) and the American Association of Science's *Benchmarks for Scientific Literacy* (AAAS, 1993), which together comprise the 'gold standard' for science education. Content knowledge recommendations of these two documents indicated that the teacher of ecology should address the following key topics:

1. Environmental heterogeneity
2. The Ecosystem
3. Succession
4. Population ecology
5. The Community
6. Life-history strategies
7. Competition
8. Predator-prey interactions
9. Niche
10. Ecological adaptation
11. Food chains/webs
12. Energy flow
13. Limiting factors
14. Carrying capacity
15. Human impact upon the environment

16. Ecosystem fragility
17. Conservation of Resources
18. Interdependencies between species
19. Mechanisms and results of evolutionary processes
20. Species diversity

The *Standards* and *Benchmarks* both call for the nature and history of science to be emphasized throughout teaching of science concepts. Science process skills are described in the *National Science Education Standards* (NRC, 1996) under ‘Abilities Necessary to do Scientific Inquiry’ and ‘Understandings about Scientific Inquiry (NRC, 1996, Content Standard A) and ‘Science as a Human Endeavor’ and ‘Nature of Scientific Knowledge (NRC, 1996, History and Nature of Science, Content Standard G). Content Standard A (Abilities Necessary to Do Scientific Inquiry) stresses the fundamental abilities to identify questions that are amenable to scientific investigation, and develop descriptions, explanations, predictions and models using evidence, to think critically about data and identify anomalies, and form cause and effect arguments, and to revise previously formulated explanations in the light of new evidence. Content Standard G holds that science should be seen as a human endeavor and social product, and as a discipline that needs many different levels and areas of ability, and one that demands common habits of mind – intellectual honesty, skepticism, tolerance of ambiguity, and open-mindedness – from its practitioners. Understanding is the final product of science and may be the fruit of observation, experiments, or both, and is often arrived at after much disagreement and postulation of competing explanations. The nature of science is revealed to a great extent by the history of science, thus the *Standards* (Content Standard G) recommend study of individuals of

great achievement in the context of their respective cultures, and the evolution of ideas through time.

The *Benchmarks for Science Literacy* (AAAS, 1993) likewise stress understanding of the nature of science as being firmly rooted in observations and explanation, and realization that the outstanding characteristic of scientific knowledge is fluidity and continual modification as new observations are made (Chapter 1: The Nature of Science). The *Benchmarks* also acknowledge the usefulness of life-stories of scientists in exemplifying the nature and practice of science, and it is here that discussion of the ‘story’ behind an ornithological image may transmit much of the gestalt of science to the student, in addition to indicating how science is a common human endeavor in which students can participate, and that ‘scientist’ implies a generic way of looking at one’s world rather than a professional label. The scientific worldview necessarily incorporates those same values and habits of mind espoused by the *Standards* (AAAS, 1993, Chapter 12), and the *Benchmarks* place particular stress upon critical response skills, as demonstrated by a student’s ability to justify assertions when challenged by the question ‘How do you know?’ This last is another fruitful possibility for the use of narrative ornithological images in the classroom, as the student constructs meaning from an image containing multiple ecological variables, and frames this meaning in terms of science concepts.

Transmitting knowledge of the nature of science to students such that a scientific worldview is internalized is not an easy task for a teacher. Sandoval and Morrison (2003) found that school science generally communicates to students a set of values suggesting that scientific knowledge is authoritarian, objective, and incontrovertibly factual – a view considerably at odds with the goals for understanding the nature of science set forth by the reform agendas. An experiment to induce understanding via inquiry-based activities was not effective in changing students’ limited

epistemology. Khishfe and Abd-El-Khalick (2002) likewise discovered that the implicit approach to developing an informed view of the nature of science was not effective, and found the most effective intervention to consist of an explicit approach with reflective elements that provide structured opportunities to reflect on aspects of the nature and history of science after explicit presentations of material. It is possible that carefully selected ornithological imagery might provide a basis for some of this valuable reflection.

As a step toward evaluating the usefulness of ornithological images to the classroom teacher attempting to incorporate the content and process skills recommended by the *Standards* and the *Benchmarks*, I re-analyzed the 40 narrative paintings and 40 field plates that were previously examined in terms of design quality. This new analysis targeted the ecology concepts listed as essential by the National Research Council and the American Association for the Advancement of Science, and also examined these works in terms of their potential for illustrating the nature and history of science.

Each narrative painting and plate was evaluated by a rubric (Appendix D) that contained a closed-response and open-response item for each of the 20 ecology concepts. Potential for instruction in the history and nature of science will be assessed in a similar fashion in a second portion of the rubric. Descriptive statistics for each genre (paintings and plates) were compiled from the closed-responses, while the open-ended responses were utilized in conjunction with the statistics to construct a picture of where and how ornithological illustration might be most valuable in the classroom.

The summarized analysis was subject to an agreement analysis (again calculating the Fleiss kappa statistic) between the conclusions of the author and those of two experienced classroom teachers and two officials of the Louisiana Ornithological Society. The panel of reviewers were

provided with a series of statements from the analysis and asked to check their degree of agreement with each. Drawing the expert panel from both the education and birding communities provided theory triangulation by using reviewers with different theoretical perspectives (Denzin, 1989).

#### CHAPTER 4: RESEARCH FINDINGS.

##### THEMES WITHIN THE LIFE STORIES OF CONTEMPORARY ORNITHOLOGICAL ILLUSTRATORS AND THE MANIFESTATION AND DEVELOPMENT OF THE NATURALIST INTELLIGENCE

The first section of this study addressed two related questions via interviews with eight contemporary bird artists:

1. What commonalities are revealed by the life-stories of a sample of eight contemporary ornithological artists? In particular, what are the conditions and factors associated with the development of expertise in both the visual arts and ornithology?
2. Is there evidence of a 'naturalist intelligence' as described by Gardner (1999) or a naturalist worldview as described by Janovy (1986/1996) in the life stories of these artists? If so, how and when does this disposition manifest, and what conditions and factors are associated with its optimal development?

As the transcripts of the interviews were coded and organized into themes, it became evident that a preoccupation with birds manifested so early in life, and that the developing interest in birds and art dominated the unfolding lives of the participants to an extent that these two subquestions must be answered in an integrated fashion. The common themes that I identified with reference to the first subquestion emerged again with reference to the second subquestion, for the lives of the ornithological illustrators are to a great extent a product of their naturalist identity and their activities within the areas of natural history, i.e., these individuals are very much what they do. The specific question of whether the naturalist intelligence manifests in these individuals, and the factors that appear important in nurturing this ability towards its full expression, is addressed at the end of this chapter following exploration of the dominant themes in the artists' stories.



Themes that emerged consistently throughout the eight interviews were validated by two independent reviewers with experience in analysis of qualitative data of this type (see Appendix F). A copy of the sections of the interview transcripts considered relevant to each theme was provided to the reviewers, who checked their agreement as a 'yes' or 'no' for each entry. An agreement analysis across the themes discerned by the author and those validated by the reviewers yielded a Fleiss Kappa value of 0.87 ( $\alpha = 0.05$ ) indicating a satisfactorily high degree of agreement.

The themes emerging from the interviews that were relevant to both subquestions one and two, and also to my primary research question concerning how the lives of these artist-naturalists might be relevant to ecological education were as follows:

Theme #1: The emergence, growth, and consolidation of a not-always conscious 'intent' to become a bird artist.

Theme #2: Issues of bird illustration as 'art' or 'science', the approaches of the artists to their practice, and the positioning of identity with respect to the labels of 'artist' and 'scientist.'

Theme #3: The nature and development of expert perception in naturalists.

Theme #4: Heroes, role models, and mentors: individuals and influences upon development of the bird artists

Theme #5: The importance of communities of practice and the 'invisible college' of bird art practitioners.

Theme #1: The Emergence, Growth, and Consolidation of a Not-Always Conscious  
'Intent' to Become a Bird Artist

A strange sense of fate became apparent as these eight ornithological artists told their life-stories, in that the surety of their paths toward becoming professional bird artists could not

be accounted for by any combination of environment and/or genetics. As Jungian psychologist James Hillman writes in *The Soul's Code: In Search of Character and Calling*: "There is more in a human life than our theories of it allow. Sooner or later something seems to call us onto a particular path. You may remember this 'something' as a signal moment in childhood when an urge out of nowhere, a fascination, a peculiar turn of events struck like an annunciation: This is what I must do, this is what I've got to have. This is who I am" (Hillman, 1996, p.3). Hillman's exploration of individual calling is framed by his 'acorn theory', which holds that the direction of lives may be shaped by an innate vision or calling, similar to the Aristotelian notion that "individuality resides in a formal cause" (p.11). The life-direction for which the acorn is the seed may or may not be apparent to a given individual in childhood, but its presence becomes inevitably becomes manifest at some point, and is somewhat independent of environment.

In several cases, this 'call' to become a bird artist was well-defined in early childhood, manifesting in indications that the individual's life was to be centered around birds, and a little later, that this would narrow to a preoccupation with the visual representation of birds in both the artistic and technical genres. The earliest childhood memories of John O'Neill, who has achieved renown as both a technical ornithologist and a narrative painter of birds, reflect an early fascination with quite mundane avian species: "It all started with birds, probably when I was about three." O'Neill recalls such experiences as spending long winter days transfixed by the activities of pigeons in the driveway of his home, and pestering his parents for scraps with which to feed them. His father brought home ducks from hunting expeditions and O'Neill begged to be allowed to keep them: "I don't know what I thought I would do with a dead duck, but I was just very much enthralled with their beauty, and the ability to have these things in my hand and look at the colors and patterns and so on". The drive to depict the birds was in place at age

four or five years, “I don’t even remember where I got the paints – but somewhere along the line I had a little box of oil paints and I started painting some birds and actually, probably about 1949 or 1950 my first painting - that still exists – was a painting that I copied of a chicken, off of some card and gave to my mother. Fortunately she kept it so I can now use it in shows.”

O’Neill also recounts – more than fifty years later – a childhood incident that would have passed unnoticed by many, but that he considers as significant as a reinforcement of his interest. On a picnic with his grandparents in the Rocky Mountains, “My grandmother put out the bread and went off to get something else and this Gray Jay flew off with the whole piece of bread in its beak. So I can still see this bird with this piece of bread almost as big as it flying off to the tree. So there are these little incidents that kind of reinforced my interest in birds”

O’Neill’s passion for all things avian grew unwaveringly throughout his elementary school years, assisted but not directed by the benign support and encouragement of his family. For example, when nine years old, he was given an early edition of Peterson’s *Field Guide to the Birds of Eastern North America*, and also a small book “with all the Audubon pictures in it.” Amazed to discover how many species of bird there were in the “world” that he had yet to discover, the young O’Neill set himself an the extraordinary task of memorizing all the plates in these books, a discipline he practiced nightly. Noting that the childish preoccupation was materializing into a serious focus, O’Neill’s mother contacted a Houston bird club and obtained a checklist of birds that had been seen in nearby counties. This seems to have loosed in O’Neill both a hunting instinct and serious scientific interest in the organisms: “And then I began to look.... I couldn’t believe that they would tell me that something like Baltimore Oriole, which is now called Northern Oriole...that they could tell me that that bird was a common bird in the spring. Why hadn’t I ever seen one? Of course, I had no binoculars and I didn’t really know

anything about, or was barely beginning to understand anything about different habitats or migration. Now I hear them all the time, yet I can go whole spring without seeing one unless I hear it sing and then look and find it because they are up in the taller parts of the trees and so on. But as a ten year old kid, I didn't see it unless it was in my face...I began to learn." O'Neill's interest was not in the least diminished by his birding frustrations, however, and he reports that by age twelve: "I was given bird books more than other things, I talked about birds I thought about birds, I looked at birds and by the time I tried to think what was the triggering factor, I was already hooked."

His lack of ability to find or see certain desirable birds resulted in an attitude toward birding, if not life, that O'Neill retains today:" even walking through the woods, if I don't find something right away, instead of waiting for something to come to me I tend to move on and look for things". This urge to "move on and look for things" also manifested in an urge to travel that was much gratified in subsequent years, for O'Neill has visited South America for (almost) thirty consecutive years in the pursuit of exotic species, "I always, even though I had no prior knowledge that I would end up traveling to different parts of the world ... .. the first chance I got in Houston to go somewhere was meeting some of the adult birdwatchers and they took me and a couple of other young friends with them to the Rio Grande valley of southern Texas. This was one of my first major distant trips and it opened up a whole new world. I have always and even today have this tremendous urge to keep going to different places and so it was natural that I would end up traveling to Peru or somewhere"

O'Neill's 'intent' continued to develop throughout his high school years as he pursued bird knowledge both alone and with the assistance of birding groups, and also continued to teach himself to paint while also studying the work of the masters. He attributes his initial trip to the

Neotropics – the avifauna of which was to provide him with material for his life’s work –and the meeting with his first mentor in ornithological art, George Sutton, as mere good fortune. In fact, both of these events may be construed as the outcome of intent, a matter of preparation meeting opportunity. O’Neill’s development of friendships with others interested in birds resulted in an introduction to Sutton at the University of Oklahoma, and the beginning of a mentoring relationship that transported O’Neill’s competence in both ornithology and painting to a new level. The unwavering obsession with birds even outside of his academic life as an undergraduate in zoology at the University of Oklahoma spurred O’Neill to take an active part in the Cleveland County Bird Club, and members of this group invited him to spend a summer in Peru. O’Neill made the very most of this trip, returning with a collection of bird specimens and paintings that prompted Sutton to send his stellar student to George Lowery at Louisiana State University, where O’Neill would have the opportunity to specialize in Neotropical ornithology.

After completing his doctorate, and becoming director of the Museum of Natural Science at LSU for five years, meanwhile enjoying a successful career in ornithology and gaining some reputation as a bird painter, the purity of O’Neill’s ‘intent’ was in danger of becoming diluted by administrative activities: “I started going to all these meetings and dealing with deans and budgets and these things. I said, “What am I doing?” I go home at night, I don’t paint, now it’s looking like I will have to stay home from Peru for awhile so I said, “I’ve had enough of this.” O’Neill promptly resigned from his position, and for a short while tried to negotiate a compromise between his identity and institutional demands. LSU created another position for O’Neill, one in which his duties lay entirely in the realm of overseeing field work at the museum, planning expeditions and arranging for funding. He withdrew from this when a change of administration added, “teaching this and that” to the roster of his duties: “I said “no way” so they

created an artist in residence which was a halftime position where I was to do ten or twelve paintings a year ... But then even that got to be too restrictive and I finally decided that I just wanted to paint on my own and just continue to do my work in Peru”. O’Neill’s autonomy was finally satisfied by accepting unpaid status as a research associate at the museum, giving him access to the museum collections, colleagues, and the University Library while allowing him to paint and conduct research in Peru as he saw fit. O’Neill retained this position for several decades, leaving only in 2005 when he decided to return with his family to Texas.

The steadfast intent that drove O’Neill as a child and undergraduate remained evident at the time of our interview (February, 2003), when O’Neill was in his early sixties. At that time he was painting plates and serving as art director for a mammoth field guide to the birds of Peru, a project that represents thirty years of ornithological research by various individuals, and that has employed thirteen professional bird illustrators. He also remains tremendously active and involved in Neotropical ornithology, having more than a decade of expeditions and book and painting projects planned, and is a great believer in constantly moving on: “my mind is always occupied with what is going to be done in the next week, months, years. In fact one of the things about our work in Peru is that we always have to be planning two or three years in advance.” O’Neill is also realistic, acknowledging that his physical capacities will become more limited – “I can always go on the river islands for example, but I had better get as much mountain climbing as I can done in the next ten or twelve years” – but it seems that the fierce intent that surfaced in a three year old child obsessed with feeding backyard chickens and drawing dead ducks is a lifelong phenomenon.

The intent focus upon birds and bird art that is exemplified in the life story of John O’Neill also appeared at an extremely early age in artists Dan Lane, Larry McQueen, and Bill

Strausberger. In common with O'Neill, Bill Strausberger of the Field Museum, now an ornithologist specializing in avian interactions and a young but already successful narrative painter, also recalls a childhood spent around domestic birds. At five years old, Strausberger recalls spending hours and days in the barn of the family farm with the ducks and chickens, "getting to recognize them as individuals and watching the different behaviors as they related to each other...I spent thousands of hours in there.' More of a loner than the other artists interviewed, as Strausberger grew in school-age, he transferred his interests to the field, and spent all his free time hiding in self-constructed blinds, watching wild birds go about their lives and business, and he credits his later skill at interpreting bird behavior to this early practice. Although he reports going to several stages of career interests, as most young children do: "by nine years old I wanted to conserve birds. I got interested in endangered species, parrots in particular, and I was going to devote the rest of my life, by any means possible, to save birds. I thought of becoming a lawyer and making millions of dollars to send in and preserve their habitats, and then I thought of becoming a scientist and going out there. Whatever it took, that's what I was going to do. And particularly parrots, I wrote letters about saving birds all the time. And I saved these letters. I thought about conserving birds, I didn't consider the painting at all. I wasn't doing it then".

Strausberger's childhood fascination with birds continued to expand, and coalesced into a firm intent to become an ornithologist in high school. His specialty is behavioral ecology, specifically the study of avian interactions, and his scientific predilections are reflected in his narrative paintings. Displaying his favorite work – showing a pair of kestrels – he commented that he puts most time and effort into the positioning of the birds in his paintings such that the ecological relationship between them tells a story. There is a barely visible mouse held in the

talons of the female kestrel: “it’s barely there, but that is what the male is looking at...what is really important in my paintings is the dynamic and interplay between the birds.” This painting was the result of years of personal experience with the species: “I’ve been working with kestrels since I was ten years old, I feel that I have put up a million kestrel nest boxes, in fact I am rehabilitating one in my kitchen right now.” Personal experience provides Strausberger with a feeling for the character, and knowledge of the ecology of the birds, and studying specimens provides the anatomical knowledge: “I have a freezer full of road kill.” Strausberger’s brimming enthusiasm for visually translating his knowledge yields a sense that this excitable and intense young man has arrived at some long-awaited destiny in the production of narrative bird art.

Strausberger’s artistic interests emerged a few years later than his birding interests; in his middle-school years. His formal education in art is limited to grade school art lessons, and his first full-background bird painting was of a pheasant, produced as a birthday present for his grandfather when Strausberger was fifteen. This was well-received and Strausberger began executing wildlife paintings to sell to hunters, partially funding his undergraduate career from this source. While Strausberger does not consider that these paintings were either scientifically accurate or of great artistic value, the practice of simply turning them out increased his technical proficiency in art to the point that he had no hesitation in picking up a brush to do some ‘serious work’ ten years later, after he had stopped painting for a few years due to the demands of graduate school. This practice does suggest that the intent to become a bird artist was lurking in the shadows of his scientific career however, and preparing him for the future.

At the time of our interview (September, 2002), Bill Strausberger was in his very early thirties. He completed his PhD at the University of Illinois in 2000 and is currently a researcher at the Field Museum. A prolific writer in the area of bird behavior, he is relatively new to the



field of ornithological illustration, having just completed his fifth ‘serious’ narrative ornithological painting at that time. His second painting – of the pair of kestrels described previously - was accepted as a cover for the Wilson bulletin and the fifth (depicting a Brown-headed Cowbird attacking the nest of a Redwing Blackbird) is being considered for a cover of The Auk.

The first memory recalled by Dan Lane of the Museum of Natural Science at Louisiana State University, is also centered upon birds. Lane was probably three years of age, when his father showed him a Brown Creeper in the backyard. He also has memories of a few family members interested in birds; a grandfather who kept cage birds, and an avid birdwatcher of an uncle who would take him out to see “something that was cool, like an owl”. Lane retains a special fondness for owls, but he said it was about four years later before he became a “diehard birder”, when he targeted birds as his special organismic group of interest: “I was an all-out naturalist first – trees, mammals, butterflies, everything...”

As with all of the artists interviewed, parental approval and a general level of family support for interests in natural history appeared to facilitate the development of a specialized interest in birds. However, the majority of the artists showed a pattern of developing their own contacts in the area outside of the family circle at an early age. Lane, for example, became aware of a neighbor “who would walk up and down the street in the springtime with a pair of binoculars around his neck.” This neighbor happened to be the president of the Montclair Bird Club in New Jersey, and approached by Lane’s mother, this gentleman was delighted to take an eight year old budding naturalist to meetings and on bird trips. Lane recalls, “I was by far the youngest person there, most of the members were in their fifties.” However, in the first year of membership, Lane traveled much of the east coast with this club, “so I got to see a lot of species

that I wouldn't be able to see (otherwise), but I also discovered that there was a lot more to my own town than I had thought...I wasn't really appreciating that until my eyes were opened by these people who had been looking at birds for many years." Although Lane lived only fifteen miles from New York City, "there was a lot of nature around, and for whatever reason, I have always been drawn to nature."

This period of Lane's young life – and that of a number of the other artists interviewed – would be described by Hillman (Hillman, 1996) as a time in which the acorn is "growing down"; a period of intense preparation when the intent becomes established as a part of the host individual's character. 'Growing down' – akin to root growth during a period of apparent dormancy – results in the construction of life circumstances that anchor the fate or calling, such as the acquisition of particular skills or of academic qualifications that establish legitimacy, or the establishment of a network of contacts and colleagues.

Becoming a bird artist requires development of skill in the visual arts as well as in ornithology, and Lane's calling to combine the two areas of expertise also manifested in his early childhood, as it did in the case of John O'Neill. Lane recalls producing crayoned field guides to backyard and neighborhood birds from the age of five years onwards: "I did one every year after that until I was about ten." Asked why he targeted birds in particular for his artistic endeavors, Lane said that he didn't know, but that he remembered being transfixed ("heavily affected") by illustrations in the first field guide he encountered at age four (*The Golden Guide to Birds*, by Chan Robbins and illustrated by Arthur Singer (Robbins, 1966)): "I was sick in bed for a long time around the age of four or five. I would copy the illustrations in crayon...I literally wore the pages out of that book and they all had to be taped back in."

Along with Doug Pratt – who is discussed later - Lane does not seem to be aware of the intent that has driven his career, but insists he has been “lucky”. The early intention is reflected in statements such as: “Again, this was something that I had decided long ago that I wanted to do, and I think that I was about twelve years old ... Right about that time I think is when a lot of big decisions in my life came together. I sort of decided then at that age what it was that I wanted to do. For one thing, at that point I was pretty entrenched in the idea that I wanted to be a bird artist. I was already pretty actively bird-watching so that was already pretty much set.” Lane was very matter of fact about this, as if it were the most natural phenomenon in the world for a twelve year old to be decided upon and already pursuing his life’s work. This is not an uncommon pattern, both with the artists interviewed for this study, and in the cases of a number of other major players on the field of ornithological illustration, such as David Sibley, Lars Jonsson, and Roger Tory Peterson.

Lane’s preparation, or ‘growing down’, involved making contact with established bird artist Don Eckelberry, reading in the semi-popular field (*Audubon* magazine) about newly discovered species of birds, and becoming familiar with current ‘names’ in tropical ornithology through his reading, specifically those of John O’Neill, Ted Parker, and their institutional affiliation with Louisiana State University. His intention became even more specific than “bird artist” in his high school years: “And I thought, I want to meet these people and I want to go to school at Louisiana State University... I know I am going to be working in South America.” Lane made relentless preparation toward realization of this new vision, taking Spanish, studying every and any field guide to Neotropical birds that he could get his hands on, obtaining tapes of the calls of birds from Central and South America and memorizing these, and taking a bachelors

degree in art. “So I trained for a long time gearing myself for doing this...it was what I have always wanted to do.”

Lane did become a graduate student at LSU a few years later – in the mid 1990’s – and there came under the artistic and ornithological mentorship of John O’Neill. Despite the fact that his life-course became apparent to him at a relatively early age, and the intense life preparation that he describes here, he describes his career then and since of one of amazing good fortune. His reaction to his acceptance at LSU, accompanied by an invitation to join a summer expedition to Peru with O’Neill, was typically humble: “I think it took me about five minutes to find my bottom jaw...I thought, this is not real, how can they possibly...they don’t know who I really am...I’ve never really been out of the country except for birding in Mexico and Belize, and that’s child’s play compared to the tropics.”

It would seem that this “luck” involved considerably good judgment on the part of LSU authorities, for on that first trip to Peru, Lane was the first person to spot a species new to ornithology, the barbet species *Capito wallasi*. Again, this stroke of “luck” involved considerable preparation on Lane’s part, having previously studied the known species of barbets in that country: “I’m honored to say that I was the first person to see that bird in the field. I spent about two hours having been the only person in the world to see that bird, which was kind of cool and as soon as I saw it I knew it was a new species to science, which was also a fluke. I had just happened to spend the day before looking through the field guides and so I knew exactly what barbets were in the world, and this didn’t fit the descriptions of any of them”. Lane’s ‘discovery’ of *Capito wallasi* “was a great thing – it was actually in some ways a terrible thing – for all that to have happened to me in such a short period of time at the age of twenty-two because I had just achieved all my life goals!” There was spontaneous laughter from both Lane

and myself and this point of the interview, but the artist was perfectly serious: “I mean, what do you do with yourself then? I struggled to find new goals!”

Lane’s intent did not fail him, however. He has since graduated with a masters degree in zoology from LSU, participated in many research expeditions to South America, contributed plates to field guides and paintings as journal covers, and now divides his time between bird art, research, and a couple of stints every year as a birding tour guide. I asked him about the future: “I hope my skill can keep up with my ambitions. When he is finished with his current assignment painting field plates for O’Neill’s *Birds of Peru*, he aims to produce a field guide to the relatively little known avifauna of Bolivia (with Van Remsen of LSU, and other ornithologists from Bolivia), and is enthusiastic about the prospect of mapping new avian territory. As in the case of O’Neill, Lane is planning ahead, thinking of his life in terms of the next decade of accomplishment, and displaying a quite emphatic and characteristic willingness to take the necessary time for quality results: “The birds (of Bolivia) are still little known, I see up to ten years to do a really good job ...I don’t know that a publisher will want to hear that”

Such publications do require an extensive commitment of time and energy on the part of their authors and illustrators: Pratt’s monograph of the Drepanidinae or Hawaiian honeycreepers (Pratt, 2005) and O’Neill’s *Birds of Peru* (Schulenberg, Stotz, & O’Neill, in prep.) are typical in taking several decades to complete. It would seem to be the both fierce and steadfast intent of their producers that brings such projects to fruition at all, as they negotiate both difficulties of changing and uncertain scientific knowledge, and more mundane issues of politics and financing.

Larry McQueen is the fourth artist of the sample whose early and obvious passion for birds was the clue to a seemingly innate disposition (Hillman’s ‘acorn’) that provided the intent and drive to deliberately prepare for what was to become an astoundingly successful career as

both an illustrator and a narrative bird painter. At 67 years of age at the time of interview, McQueen is both the most senior of the artists interviewed for this study, and also the one individual cited by each of the other participant artists as a living bird artist that they particularly admired.

McQueen is a quiet and unassuming man, and I found it quite extraordinarily difficult to propel him to talk about himself for any length of time during the interview, although he was eloquent upon the subjects of art and science in more general terms. He was quite clear, however, about the force and direction of the intent that had possessed him and directed the course of his life since early childhood: “My interest (in birds) was ingrained early on...they (birds) were my life’s ambition...I was completely focused on birds in my childhood and part of that focus was drawing them. School was a side-track.” He also reports being interested in other aspects of the natural world, but birds were his first passion and never lost their primary importance to him. As with the other artists in this study, an interest in birds (the chosen organism), obscures but does not eliminate an interest in other groups.

In common with O’Neill, Strausberger, and Lane, Larry McQueen’s first childhood memories involve birds. He recalls being three years old, watching cardinals and robins in his backyard, and becoming aware of differences between the species: “I could chase the robins, while the cardinals flew away!” He drew birds as he increasingly focused upon these organisms, “because drawing helped me see better” and reports that other activities – such as school – were perceived by him as an irritant and distraction from his primary purpose – to watch and learn about birds. McQueen was one of only three of the artists in the study (see also Eustace Barnes and Jim Coe) who was able to articulate the particular drawing power that birds held for him. In a rare moment of spontaneity during the interview, McQueen offered the suggestion that many

bird lovers are attracted by the illusion of freedom offered by the power of flight: “we know of course that birds are not actually any freer than any other form of life, but I think we are attracted by that freedom and try to emulate it.”

In addition to observing birds in the field, the young McQueen developed a passion for illustrated bird books, and haunted bookstores and libraries – even in elementary school – in search of more of these publications. He loved nature and was interested in “anything and everything” in the natural world, but birds were his passion. Moreover, he fervently believes that the naturalist who is to become an expert ‘intuitive’ birder must anchor this expertise in a focus that begins in early childhood, and persists throughout life: “It really is true about birders, especially when very young...there has to be an obsession, a total interest that doesn’t necessarily exclude other activities, but these must always take second place”. Note that all the artists discussed thus far are quite matter of fact about a degree of single-mindedness in a child that most people would consider extraordinary. There is no idea of balance, of well roundedness, that is conceivable to those possessed by the intent of an O’Neill, Strausberger, Lane, or a McQueen.

In college, McQueen majored in wildlife biology, but no bird-related jobs were available to him upon graduation, with the exception of game bird management, an area that did not interest him. That the very idea of participating in applied ornithology seemed to offend McQueen’s sense of integrity speaks of the purity of intent in this humble and soft-spoken artist: McQueen’s one departure from his birding pursuits occurred when he was drafted into the army after college. His passion and intent remained intact, however, and on his return to civilian life he made a conscious decision to return to school to study art. He followed this path not with the desire to obtain a professional qualification, but merely to learn techniques that would support his goal of becoming a bird artist. This is yet another example of how a childhood dream is

gradually and persistently translated into action as decisions are made to support that intention throughout life, and the same phenomenon is manifested time and again in the lives of the other artists interviewed.

McQueen did get sidetracked for a few years in the 1970's, when the necessity to earn money for survival resulted in his taking employment as a graphic artist for a few years. But his intention continued to plague him, and he eventually decided to go for it, and set up as an independent bird artist: "My first commission led to more employment... and today...its tough but you can make a living at it (bird art)." Today, he remains a very active birder, and spoke excitedly of new observations, seeing new species, and the annual thrill he feels at migration time. His childhood intent has become a reality, manifesting in much recognition and admiration among his peers, and a successful career as both illustrator and painter of narratives.

The remaining four of the artists interviewed - Eustace Barnes, Jim Coe, Doug Pratt, and Sophie Webb – did not have their life course made so apparent to them at quite such a young age as did Lane, McQueen, O'Neill, and Strausberger. This is not to say that the intention or 'acorn' was not present, for though their early life histories suggest that these individuals might have "drifted unknowingly" (Hillman, 1996, p.3), but their actions and preparation for life and their dedication to both ornithological and artistic pursuits, strongly suggest that while they had not consciously decided to become professional bird artists, they somehow felt "answerable to an innate image" (p.4), which was a guiding force in the shaping of their biographies. Hillman labels this force that shapes a life even when the intent is not obvious to the individual in question, as a "daimon" (p.5) that guides the development (or 'growing down' – p.41) of a life whose initial blueprint is contained within an "acorn" (p.3).



The childhood of Eustace Barnes was much concerned with birds and art, and there are indications that this artist also possessed the innate disposition or intent to become a bird artist, although it was not fully articulated until his mid-twenties. He was also involved with birds from childhood, in addition to other outdoor pursuits. Raised in an artistic family, Barnes was actually discouraged by his academic artist parents from art as a career: “they didn’t see art as a real job.” However, it was impressed upon him from an early age, that a career should also be a vocation or that “work should be a paid hobby”, thus “sitting behind a desk from nine to five would not be regarded as a success by them.” Barnes reports that he received the most praise from his parents from “getting out and doing what I enjoyed. My mother was interested in botany and they supported my interests in outdoor pursuits and wildlife...so I followed through with my own interests in biological matters and art.”

Barnes first learned to identify birds as a child, from an interested friend of the family who would take him out and also take time to explain, “Why things were what they were. People like that are very valuable educators” He learned to draw birds “by doing it. All the time. I started when I was about eight, and every time I got a chance to do a project at school, it was always about birds.” This artist did offer an interesting insight into why birds in particular attracted his attention from among his other outdoor interests and occupations. Although birds are, he thinks, generically attractive to children because “birds move and that’s attractive to a child”, and he acknowledges the influence of the people around him who knew a little and helped move his interest along – important to a doer - Barnes also believes that birding is a sanitized expression of a basic human hunting and tracking instinct, one which is thwarted in many modern cultures. Barnes had also mentioned being a “keen hunter“ himself in his early years: “and some people are very good hunters, and others don’t seem to have a clue...it’s the

hunters who make good birders.” This has a ring of historical truth, for a number of accomplished birdmen and artists also learned their birding skills as an accessory to their hunting activities, including John James Audubon, Robert Bateman, Lars Jonsson, and Bruno Liljefors.

Although sounding casual about his childhood interest in art, Barnes did mention that he won a number of art competitions in this period for his bird paintings. There was no explicit intention to pursue professional ornithology or bird art at this time, but there were definite indications by the end of his high school years that the intent was in place – albeit still unconsciously – and that the acorn was growing down. Barnes chose the unusual combination of Geography, Biology, and Art for A levels (Advanced level); courses that lead to examinations determining university entrance in Great Britain. In that country, selection of the three A level subjects is akin to declaring a major in the United States, and it is only with considerable difficulty that the direction of one’s professional life can be changed after this decision, at least insofar as higher education is concerned. This generated some controversy and argument at school, because subjects are almost never grouped so randomly: art is to be taken with languages or humanities subjects, and biology is almost invariably accompanied by chemistry and physics study. Although Barnes rationalized his choices as “giving me the broadest options for the future” it is quite possible that on some level he had decided upon that future, one that was eventually to combine travel, birds, and painting.

Barnes continued in the same vein, selecting biogeography as an undergraduate major, since at the particular British university he attended, this direction allowed him the most freedom to chart his own course with respect to biology and ecology courses taken. Art he felt he could pursue independently of formal education, and also, “I had had all that at home.” When asked why he had no overt ambitions at that time to take up art, Barnes explained that after much

exposure to the art college culture via his family background, he considered denizens of that world to be lacking in focus and too unconcerned with production. Like the other participants of this study, Barnes is a ‘doer’ as well as a dreamer, and a highly focused individual who is much concerned with productivity.

His artistic and birding pursuits continued to be serious hobbies during the next few years when he obtained a masters degree in tropical ecology (again from a British institution) and then trained to become a science teacher. I enquired whether Barnes had ever overtly considered becoming a professional bird artist during his years in higher education, for his choices and pursuits do indicate that he was ‘growing down’ into a realization of this intention. He did not consider this a realistic option in the United Kingdom due to lack of financial support for the profession, although he envied the perceived opportunities that academic bird artists in the United States - such as John O’Neill – have to do research and paint under the auspices of a university.

Since Barnes felt that the teaching burden imposed by academic life at British universities would not allow him sufficient time for birding and painting (“I would have ended up a strict scientist with little time left to explore and paint”), he elected a career in secondary school teaching that lasted some six years, until “the vagaries of bureaucracy caught up with me”, and like John O’Neill and Larry McQueen, he decided that autonomy and freedom to pursue his painting must take priority over financial security. The intent surfaced, and the years of preparation in painting, birding, and studying ecology provided reinforcement for his decision: “I left (teaching) to become a tour guide and illustrator. I had organized and guided trips privately while I was teaching, and undertaken enough commissioned paintings of Neotropical birds ...I thought I could find a way to survive.”

In September 2002, at the time of interview during the North American Ornithological Conference in New Orleans, Barnes had become established both as a field guide illustrator (he has been the sole illustrator of three guides to Neotropical bird species, and there is a growing and thriving market in the United Kingdom for his narrative works) and continues to lead birding tours in Bolivia, Brazil, Peru, and Venezuela, both as an outlet for his teaching drive and as a way to discover and track new species of birds. In common with Dan Lane, Doug Pratt, and Sophie Webb, he tends to regard his career as a series of happy accidents rather than expression of an innate intent, but the unfolding of his life supports Hillman's acorn theory nonetheless. As for the future, he feels he has 'arrived' and is generally content with his status as a bird painter, although he expressed an unfulfilled desire for involvement in ornithological research in the tropics: "If all financial constraints were removed, I would still paint birds. I would carry on with the same projects that I'm working on at the moment in terms of painting, but I wouldn't guide tours ... It would be good to work organize and conduct my own research, which would probably relate to two things that I'm particularly interested in - dynamics with avian communities in the tropics and historical biogeography".

The development of Jim Coe's career as a bird artist has some commonalities with that of Eustace Barnes. Like Barnes, Coe is an individual who has always been an artist and dedicated birdman, but one whose intent to combine these passions into the profession of bird artist was not clear early on, rather coalescing in his mid-twenties, after a considerable amount of 'growing down' into both biology and the visual arts. Coe said little about his very early childhood, but reported that a generalized childhood interest in outdoor pursuits underwent a rapid growth spurt in his early teens, supported by two key individuals: a like-minded friend with whom he explored local woods and marshes in New England, and the medical doctor father of this friend, who

encouraged this interest in science by providing the two with a variety of specimens. Birds initially caught Coe's interest, although he was later to become interested in other areas of natural history, including butterflies and botany. Coe was one of the artists interviewed – Sophie Webb the other – who recalls a specific moment at which his ornithological interest materialized, one of Hillman's "signal moments" of childhood. Exploring a local marsh with friends at ten years old, Coe recalls that, "Something clicked...there was this particular place that had a little tidal marsh running through it, and I remember being struck by an Egret's yellow legs and then looking at those of other shorebirds in that marsh." Following that incident, Coe became a devoted birdwatcher, finding new friends to support this interest and studied field guides at home between birding trips to elaborate upon his knowledge of previous sightings and to clarify his ideas about what aspects of birds to concentrate upon.

I asked Coe to consider why birds attracted his interest first, as they do for many children, and he gave this careful consideration. He believes that the sheer ubiquity of plant life makes it less likely that something will catch the attention of an untrained eye, and that differentiating plants by anything other than flower morphology and color takes skill and education. Insects are also complex, and numerous, and fossils are conceptually beyond the majority of children. "But birds are easy, any kid can get a field guide, and go out with a pair of binoculars, or simply to a feeder and learn to identify the common birds"

Coe's interest in the visual arts emerged in his early adolescence, and underwent a period of 'growing down' during his teens, developing alongside his biological interests. A subscription to *National Wildlife* magazine, which published reproductions of bird artists' work, fed his growing appetite for bird illustration and introduced him to the work of Don Eckelberry. The intent toward a profession in bird painting seemed to emerge at this time, and with the

encouragement of a high school teacher, Coe wrote to Eckelberry and received an invitation to visit Eckelberry's studio for help and advice. Coe was still unconvinced of his eventual path, and although continuing to paint, became set upon the idea of becoming an academic ornithologist, and entered Harvard University to major in biology: "I dreamed of being an artist when I was in high school and I was learning that I had proficiency in art. But while I was in college I felt strongly that I was headed toward a career as an ornithologist ... in science. It wasn't until later in my college years that I felt that I needed to put the brakes on and take a break from science and try alternate pursuits – as an artist. I knew I had skills; I just had never given it a shot. I finished college and took a break from academics – from science – and focused on my painting. I was actually working on a field guide project at the time; I was illustrating a few plates for the birds of New Guinea. I was doing my paintings, working on my field guide plates, and working at my job to pay the rent."

The idea of graduate study in ornithology became distasteful to Coe as he increasingly came to perceive academic life as overly restrictive, much as in the cases of O'Neill and Barnes. After completing an MFA at Parsons School of Design in New York City, and continuing to bird very actively around the state, Coe was well prepared to begin his professional career as his life-course finally became apparent to him: "My first year out of art school....I very much didn't want to get a regular job that would use the time I would otherwise spend painting. I needed to paint in order to progress as an artist."

Coe took the plunge (as did all the artists interviewed) and wrote a proposal for a field guide for urban birders in the Northeastern United States, and a contact in publishing attempted to sell the idea for him. A receptive publisher – Golden Books – liked Coe's work but dismissed the original idea of the urban guide, but went on to offer Coe a contract for a new field guide

aimed at the beginning birdwatcher. Coe set to work developing the idea: “and then I tried to devise a really good proposal that would supplement what was already out in the market rather than rehash another guide that had already been published. And having just got out of art school I was interested in developing and illustrating a field guide in a way that would allow me to incorporate a little more artistry in the illustrations and less technical approach.” The result was Coe’s *Eastern Birds* (Coe, 2001), a guide that received glowing reviews in the birding press, and has become popular with high school and college teachers.

Since publication of *Eastern Birds*, the artist in Coe has overtaken the illustrator, and he has made a successful practice of *pleine aire* landscapes, narrative paintings that never fail to incorporate a bird subject. Although Coe’s field guide was initially a two-book contract, the bankruptcy of the publisher put the publication of the companion guide to western birds of the United States on hold. At time of interview, the contract was being re-negotiated, and Coe had completed more than half the plates. His reservations about this project are more than financial, however: “I’m having so much fun with my bird in landscape paintings, and they are selling...it would be hard to go back to the sheer discipline of producing a field guide.” Although in one sense – artistically – Coe has proven himself as competent in technical expression and is currently enjoying exploring his own creativity, he will remain a painter of birds: “I am still so interested in birds, always, always painting birds... I still have this passion for bird-watching...for looking at and painting birds.” One might say that Coe has arrived at the full expression of his innate intention. He has ‘grown down’ into his powers, served his time in skill development, and now presents himself as a man fundamentally and serenely attached to his identity.

Author and illustrator Douglas Pratt, accorded ‘guru’ status in the classification system used here for his expertise in technical bird illustration, and the scope and length of his career in

the field, is an exception to the other two artists in the category of ‘guru’, in that his intent was not necessarily clear to him in his early years. Evidence that the ‘acorn’ was present appeared repeatedly as his life story unfolded. Pratt, like Lane, spoke repeatedly throughout the interview of “most fortuitous events”, “amazing good luck”, and that of always being “in the right place at the right time.” It will be clear from his story however, that this good fortune was always a matter of preparation meeting the inevitable opportunity – as is also the case with Dan Lane - and that Pratt’s intention toward becoming a bird artist directed much of his life’s activity.

Pratt is unusual within this sample of ornithologist artists, in that he presents himself very much as a pragmatist, and without exception, the remaining seven artists are quite explicitly idealistic. His first venture into bird art typifies this attitude.

In common, with Lane, O’Neill, and Webb, Pratt made notebooks and journals about birds in his early elementary school years. Although he admits, “I’ve been interested in birds and art since I was just a little kid”, Pratt’s pragmatism asserted itself even then: “Art was just a tool for me... I’d cut bird pictures out of magazines and such when I could find them, but if I needed a picture and couldn’t find one somewhere I’d draw it myself and so it (art) has always just been a utilitarian thing to me.”

Pratt emphatically denies that he nurtured any aspirations toward a life spent painting birds: “I did not set out to become a professional bird artist. But I ended up that way just by circumstances and I always like to say that the hobby got out of hand.” Despite Pratt’s work, his intention revealed itself by its “growing down”, the independent learning he did concerning birds all his life until he entered a doctoral program in ornithology, and by the fact that he kept painting, never abandoning the pursuit although he claims no innate talent, and that the subjects of these paintings were - solely and invariably - birds.



As in the case of the other artists, in early childhood Pratt encountered a generalized level of family support for his birding interests, but no direct tuition or involvement. However, he found himself a mentor in a field guide, Roger Tory Peterson's *A Field Guide to the Birds of Eastern North America*: "I used his book like a bible when I was a kid, chasing birds around North Carolina." He continued to teach himself about birds, and also appears to have connected with local birding groups in his high school years. Although Pratt did not overtly profess to an overwhelming passion for birds during this time, he recounted an incident from his early teens that demonstrates the real depth of his enthusiasm, and the extent to which he was 'growing down' as a potential ornithologist: "I had one of those born-again experiences (Pratt was laughing as he spoke, but brimming with excitement at the memory and obviously quite sincere) when Peterson brought out his new edition of the *Field Guide to Western Birds* in 1961. He had a section on birds of Hawaii. I had never thought about birds of Hawaii before; I knew that they must have birds but I wasn't particularly interested. Well that section ... I bought the book the first time I saw it on the newsstand, I remember the day. I spent the whole rest of the day in the section on Hawaii, literally reading through the species accounts. I mean the Peterson Guide is not something that you fan the fire with usually, but that just really fascinated me ...it announced the discoveries of these rare birds in a swamp, and I thought, "this sounds wonderful, to go into these places and find 'extinct' birds", and one of these days I am going to get out there and see those things. I have just got to do it." The opportunity was presented to him almost exactly ten years later.

This vivid image of a fifteen year old boy spending an entire day reading a new field guide, and having his imagination fired to an extent that he can viscerally recall the experience four decades later speaks eloquently of the passion that Pratt did not acknowledge to himself.

However, he was sufficiently self-aware to elect to major in biology, at Davison College in North Carolina, and it was during his undergraduate years that he had his first inklings that he could possibly become both an ornithologist and a bird painter. The coalescing intention to become an ornithologist was evident to others: “my favorite professor was an entomologist and botanist. One day I just remarked, “I think I’ll become an ornithologist, and he said, “Well, you’d be crazy if you didn’t because I have never seen you without a pair of binoculars...” Also at this time, Pratt’s first “vague idea” that he could do some bird illustrations professionally surfaced. When giving a talk for the local (Charlotte, NC) Audubon society as an undergraduate, Pratt found himself without slides, and instead drew a number of illustrations from memory and reference books. He had continued painting birds in a somewhat desultory fashion, made some local contacts with other bird artists (“Before I moved to Louisiana I had picked up a lot of information from a couple of bird artists I knew in the Carolinas”) and had also begun to take an interest in the work of major contemporary bird painters.

One of the bird artists that Pratt most admired at this period was the legendary late George Sutton, an exploratory ornithologist and narrative painter of international reputation, and at that time, Professor of Zoology at the University of Oklahoma. A meeting with Sutton, again attributed to ‘luck’ but actually a result of Pratt’s continuing interest in and study of birds, provided a sort of quantum leap forward in his increasing disposition toward bird art. Pratt is a great raconteur, and the story of this encounter is best told in his own words: “I made a trip – a brief visit actually but it was very influential – to George Sutton in Oklahoma ... That was a very important influence. I dropped in on him unannounced and just hoping he would be there - I was on a bird watching trip to the Southwest with a buddy at the time. But we found him at Lake Texoma Field Station in Oklahoma, and by coincidence he was giving a lecture that evening

about bird art and had a bunch of his originals out on display. Of course, I went and drooled over them and I remember at the time though looking at them and having one of those “aha!” experiences. I could look at them and say “Now I see – I see how you would do that”. And I went home from that trip and painted three of the best paintings I had ever painted in my life that looked like an entirely different person had done them. It was just a dramatic order of magnitude jump all of a sudden just from that one experience, one brush with greatness you might say. And the whole thing dates from there.”

Pratt’s falling in love with professional bird art may have dated from his encounter with Sutton, but his intention seems to have remained in its “growing down” stage, for over the next few years, Pratt stayed with his original ambition to become a high school biology teacher, as did Eustace Barnes. He enjoyed teaching, but became restless - Pratt is an energetic and restless individual, and it is difficult to imagine him as part of a school routine. He decided to take a graduate degree and become a college teacher, still not acknowledging or fully aware of the emerging of his intention to pursue bird art. However, he did indicate that one reason for his choice of LSU, along with the reputation of the Museum of Natural Science director George Lowery, was that it seemed like a fertile environment to pursue his interest in bird art, given the presence of John O’Neill and assorted other artists associated with that institution. His interest in academic ornithology waned after completion of his doctorate, by which time he was sufficiently established as a bird artist to pursue the area professionally. At LSU and with the examples and input from other bird illustrators, Pratt says, “I got better at it: more than I expected to or had ever really thought that I could.” He continues to deny any conscious intention: “I never really set out to be a bird artist. I sort of discovered that I could do it, *and I kept at it...*and people seemed to like what I did...*and so I kept at it...*and now I like my work!

Pratt seemed not to care for harping upon discipline and preparation; he prefers to marvel at his good fortune in life, presenting himself as a chap who is always in the right place at the right time when the right person with the right opportunity comes along. If he is to be taken at face value, offers of commissioned work fall generously from the sky: he fails to mention the hours spent in the field and with books as an amateur bird-lover, the demands of graduate school, and the years of patience teaching himself the techniques of art. Pratt sees nothing remarkable about either his passion or consistent discipline, and continued to insist throughout the interview that his career was the product of continuing ‘good luck.’

Mention has been made previously of Pratt’s childhood fascination with the Hawaiian Islands and their avifauna. Preparation met opportunity and allowed Pratt’s intention to discover its usual ‘luck’ when Pratt made friends with a Hawaiian graduate student in ornithology – Philip Bruner – at the LSU Museum of Natural Science in 1971. The two began birding and collecting together in Louisiana, and when Bruner finished his degree and returned home to Hawaii, Pratt was invited for a visit. Once there, Pratt met other members of the ornithological community, they talked birds for days and weeks, and the result was a field guide to the entire Hawaiian region published thirteen years later (Pratt, 1987). In the intervening years, Pratt endeared himself to the Hawaiian community by producing artwork for free for local Audubon Society Publications, and became sufficiently familiar with the Hawaiian honeycreepers that he felt able to question the prevailing taxonomic classification, and at last found himself a dissertation topic, resolving a problem that was plaguing him in graduate school. “I revised everything there. My fieldwork involved studying things that nobody had ever brought into the mix before. In other words, all the classification up until then had been done by just looking at dead birds in museum

trays. I started looking at behavior, nest building, breeding biology and particularly vocalizations.” The ensuing research required extended stays in Hawaii, some of which Pratt financed with grants, and the remainder he made up with commissioned artwork, such as his series of bird paintings for the state of Hawaii. The theme continues and extends itself: Pratt applies himself, teaches himself, surrounds himself with others who can either appreciate his expertise or help further it, and calls the fortunate results “good luck”. There is much evident here of a solid determination to pursue this particular career path, Pratt’s intent remained steady, if circumspect, for decades. During this time, Pratt was most productive, leading tours, painting a diorama for the museum at Brigham Young University, making voluminous recordings of birds that are now archived at the Cornell Lab of ornithology, and doing the groundwork for a number of books.

Another “fortuitous instance” was being offered the opportunity to be the principal illustrator on the first edition of the *National Geographic Field Guide to Birds of North America* the year he graduated (1979). This kept him employed for three years, and established him as a professional bird illustrator. Pratt speaks as though this career decision was made for him by fate, but much preparation was involved in both science and the visual arts. As a graduate student, Pratt was taken to a social evening (by O’Neill) at the house of Don Eckelberry, where he met Al Gilbert, Roger Tory Peterson, Arthur Singer, an experience he describes as “dining with the gods.” He was asked to show some of his favorite work – which at that time was, and remains, a series of paintings of Hawaiian birds for a Hawaiian State Foundation (done in the mid 1970’s, Pratt says, “they were a major breakthrough”). When Arthur Singer pronounced these “very good work”, Pratt, still coloring with pleasure at the memory, said he felt had truly arrived in the world of bird art: “I had an endorsement from the Pope!” This meeting turned out to be the

cornerstone of Pratt's illustrating career, for shortly afterward, he was offered publication of these paintings in *National Wildlife* – an opportunity that manifested upon the endorsement of Eckelberry, Gilbert, and Peterson. After the appearance of this work, the National Geographic Society offered Pratt a contract to illustrate their first field guide, cementing Pratt's status as a professional illustrator.

The National Geographic Guide made Pratt's reputation: "Because that was really a tour de force, you had to do all sorts of different kinds of birds and it wasn't just the birds, you had to do the background material and run a gauntlet of critics and so forth. It was good experience. I learned how to be an illustrator doing that book. And it still holds up after twenty years."

Pratt has been kept busy with writing about and illustrating birds since that time. At time of interview (October, 2002), he was attempting to get his monograph on the Hawaiian honeycreepers (Pratt, 2005) to press, and also finishing the illustrations for a biography of world birding record hold Phoebe Snetzinger (Snetzinger, 2003), a woman who after being diagnosed with terminal cancer set out to break the world record for the number of birds seen by one individual. Pratt obviously appreciates this degree of dedication and doggedness in the face of difficulty, and recounts with satisfaction "but she didn't die of cancer, she died doing what she loved (Snetzinger was killed in an automobile accident on a birding trip) having just seen her 8000-plus lifer." And of the illustration assignment, he says; "It is quite a thrill because I knew Phoebe and her family (Phoebe Snetzinger's son Tom is author of her biography and an ornithologist friend of Pratt who works in Hawaii), and also because the nature of the work is painting 45 of the neatest birds in the world!" Pratt sounded so triumphant that we both laughed spontaneously at his loud enthusiasm.

When I asked about his future plans, Pratt's replies conveyed a contentment and satisfaction with his realized life as a bird artist. Doug Pratt is one of those individuals who seems to have been born busy, and he planned to remain so at time of interview. He is currently set to continue in illustration work, producing two new field guides to replace one earlier work (*Field guide to the Birds of Hawaii and the Tropical Pacific*; Pratt, 1987), one which is an updated field guide limited to Hawaii and Micronesia, and another that is a more academic handbook on the birds of the entire South Pacific region. For the former, he will do double duty as both author and illustrator, roles that he is confident he can fulfill: "This is the area where I go birding, and as I describe the birds I know what users need to know about the species to identify it."

The biography of painter Sophie Webb has much in common with her contemporary and friend Jim Coe, as one who spent the first twenty-five years of life in diligent preparation for a profession, driven by an intent that only became fully apparent to her as she achieved recognition and reward for her work. Although Webb never articulated the intention to become a bird painter to herself, the following brief life story will demonstrate how Hillman's acorn seems to have been present nonetheless, and how its subsequent growth directed the course of her life. Now an established technical illustrator of birds, and one of the select group of bird artists chosen by O'Neill to contribute plates to *The Birds of Peru* (Schulenberg, Stotz, & O'Neill, 2006), in recent years Webb has expanded her professional repertoire into the illustration of children's books about birds. Her first production, *My Season with Penguins* (Webb, 2000) – a tale distilled from her three years of research activities in the Antarctic – became a best seller within its literary class and received numerous awards. The subsequent volume, *Looking for*

*Seabirds* (Webb, 2004) has likewise met with much acclaim from the literary world and the marketplace.

Although Webb is among the four artists interviewed whose career path as a bird illustrator did not become immediately clear to her in childhood, her early disposition toward the natural world was evident to her at a very early age, and continued to manifest in her choice of leisure, academic, and professional activities. During the interview in her studio in Salinas, California, she frequently recalled incidents from her early years growing up on Cape Cod, and her lifelong fascination with marine life, and seabirds in particular.

In contrast to Doug Pratt, who first became interested in birds and then taught himself to draw those species he could not find pictures of, Sophie's intention manifested itself early in the artistic realm; "I was first an artist who loved animals...I drew ever since I was a little kid." Webb is now a field biologist much in demand by research organizations and institutions for her skills, but she began her higher education in art school, later changed her major to biology at Boston University and supplemented these studies with courses in scientific illustration at Harvard Museum of Comparative Zoology.

As a child who passionately loved art and animals, Webb acquired the habit of making up journals based on imaginary lives, such as "when I was in the sixth grade, I made up a journal about my experiences on an African safari when we were studying Africa in school." She based other journals on ideas she picked up from her vociferous reading or her limited television viewing: "My parents were strict about TV, but I was always allowed to watch things like National Geographic or Jacques Costeau specials. I had this fantasy life of going off to live in some remote place with animals...I was going to be Jane Goodall or Jacques Costeau at the very least..." This is probably not an unusual fantasy among children, but Webb's drive and intent



made it concrete through the medium of the biological and artistic skills she determinedly developed in her future life. The fantasy has been at least in part realized: at the time of interview she lived in a rented cabin in a remote region of Northern California, and has spent much of her working life in isolated areas of South America and the Polar Regions.

As in the case of Jim Coe, the ornithological interests of Sophie Webb materialized in a specific incident, a moment she recalls with great clarity: “It was when I really looked at a bird for the first time...I was at Audubon Camp (age seven) and I remember getting so excited...I have a really intense memory of seeing an Eastern Bluebird sitting on a post out a field.” Webb exhibited many other signs of a generalized biophilia throughout her childhood years, although her decision to specialize in ornithology did not become firm until her early college years. She refers to her passion for seabirds as something innate, although stimulated by her environment: “Growing up on Cape Cod, I always really loved the ocean...it seems my interest in seabirds has just always been there”

Webb scoured the seashore and surrounding countryside to find bones, shells, and other natural objects, collected books about animals that she still remembers in great detail, kept a multitude of pets, was a devotee of natural history museums, and as described previously kept numerous journals and sketchbooks devoted to natural history. During her years as an undergraduate biology major at Boston University, Webb was involved in many extracurricular projects in natural history. Although she “was fortunate enough not to have to work for financial reasons,” she elected volunteer work at the New England Aquarium, and volunteered for laboratory research and lab teaching assignments at the university. Webb also recalls always having a sketchbook with her during her college years, making visual notes of every organism

she encountered on her projects, and continues this practice today;; it was her personal journal on her Antarctic expeditions that provided the material for her first children's book.

College was followed by several internships in which Webb worked on field projects involving birds in New Mexico, the Galapagos Islands, Australia, and at the Point Reyes Bird Observatory in California. Her migration to the northern California coast (where she maintained a home base for many years, still resident in the same cabin where this interview was conducted in 2003) was driven by her urge to study seabirds. She became more involved with land birds later when working on the Mexican field guide, but seabirds have always been and remain her area of intrinsic interest.

Although the career of professional bird artist had still not occurred to Webb, this post-college period of internships seems to have been a valuable period of 'growing down' in the area of field ornithology. She had eventually intended to pursue graduate studies in field ornithology, but this plan was interrupted when her colleague at Point Reyes – Steve Howell – suggested that she illustrate a field guide to the birds of Mexico that he was currently researching (Howell & Webb, 1995), and the chapter in Webb's life that might be entitled "Professional Bird Artist" began.

The making of *A Guide to the Birds of Mexico and Northern Central America* (Howell & Webb, 1995) took years longer than anticipated, during which Webb and Howell lived an itinerant life, based in a tiny cabin on the point Reyes property, but spending months in Mexico doing research for the book, and then returning to New York where Sophie used the collections of the American Museum of Natural History as references for her finished paintings. Sophie speaks with gratitude of this support and encouragement of this institution, for at that time she and Howell were in their mid-twenties and lacking higher degrees, they felt that they lacked

academic legitimacy. In response they formed an obstinate self-image: “we were field biologists; it was us against the academic world...it’s kind of funny.” She believes that it was Howell’s ornithological brilliance that overrode the lack of academic credentials and gave the pair entrée into the museum world, gained the support of the museum and of other academic biologists.

After publication of the Mexico Guide, Howell and Webb began working on a guide to Chilean bird. Sophie spent months every year in Chile and incorporated three cruises to study the seabirds of the region. Funding this project became a significant issue: field guides in areas of natural history are not considered products either of the sciences or the humanities, and it is not easy to find appropriate funding sources. Sophie worked on censusing projects and doing private illustration work, and Howell worked as a bird guide while they were researching the guide, which Webb said was more than half-completed at the time of this interview. Webb’s first research trip to the Antarctic occurred during this period, in the mid 1990’s. She has since spent five seasons working on penguin projects in the Antarctic, and as mentioned previously, her illustrated journal formed the basis of her first children’s book.

The studio where the interview took place contained an entire wall of Sophie’s journals and sketchbooks: she is the most inveterate of all the artists in the sample in terms of recording her impressions of the natural world visually, and is also a great taker of notes and dissector of observations. Her professional and personal life is very full (and the two lives are much interwoven, as with all of the artists interviewed) but she continues to keep journals regularly, and writes more fully and intensely during her frequent travels. Webb firmly believes that writing, like drawing, strengthens her powers of observation, and that at ‘critical’ times – such as on a research trip – her sensitivity increases, and her need for the active reflection provided by these activities is greater.

We talked at some length about Sophie's work habits, and also the personal meaning she assigns to the illustration and writing projects that comprise her realized life at this stage. She spoke much of the importance of time to allow art projects or writing to come to fruition, and the necessity of tolerating the discomfort of working on multiple projects in order to allow for this time while remaining productive: "Although it is difficult working on several things at once, I don't think I would be happy or productive working on just one project. It takes a while for things to gel or coalesce in my mind – the children's book took about three years – what's going on right now (her assignment painting plates for O'Neill's *Birds of Peru*) is the last phase. This is constant effort, really intense, when the idea is finally together and I have to get it all out." Working on several different projects simultaneously allows Sophie to "use different parts of my mind, its more efficient for me to spend part of the time on technical things, and part of the time on freer and more creative projects."

Like her friend and contemporary Jim Coe, Sophie has a distinctly creative bent, and finds painting field guide plates arduous: "I have to get myself into a different frame of mind. The whole point of the illustrations is that they be as accurate as possible, so people can identify the birds...as time goes on it is harder to work in that mode than it used to be. I definitely try to make the plate attractive, grouping species that should be together etc, but also to make the composition balanced". The personal trade-off is that Sophie feels she is making a contribution to science, and possibly to the long-term survival of the species by creating accurate visual records of species. She also believes the eye of a trained and knowledgeable artist contributes more to these records than even the best photographs; that observations require skilled interpretation, and - echoing John Dewey, Eustace Barnes, and John O'Neill – that seeing involves an array of skills and sensitivities beyond mere 'looking'.

Webb is a self-described perfectionist in her more technical work, reworking writing and field plates constantly, and combining this aspect of her life with her more creative endeavors is the formula that allows her greater comfort, success, and productivity in both areas. She continues to participate in research cruises as a technical observer, and finds material and ideas for her children's books there. She says that of all her professional activities, her narrative paintings for her children's books give her more personal satisfaction. She can make subjects she loves interesting to children without constraint : "I can put birds in what I consider the most interesting and meaningful positions; they don't always have to be in side view, and if I don't think the undertail coverts are a big deal in the life of the bird, I don't have to show them!" Another aspect of writing children's books about birds that Sophie values is the freedom to insert conservation material: "It is about the different groups of birds as part of the ecosystem, includes the basics of the ecosystem, aspects of oceanography relevant to bird life, and conservation issues that affect seabirds such as plastics disposal, oil spills, pollution, overfishing..." A key factor in the development of Sophie Webb's disposition toward bird art seems to be an unshakeable conservationist ethic rooted in her childhood pleasure in the outdoors as she grew up on Cape Cod. Sophie lacks the mentality or disposition of a campaigner, but her enthusiasm for working on children's books is at least partially fueled by her belief that selling children on the magic of the outdoors is the key to raising a generation of those who would conserve it.

Theme #2: Issues of Bird Illustration as 'Art' or 'Science', the Approaches of the Artists to Their Practice, and the Positioning of Identity With Respect to the Labels of 'Artist' and 'Scientist.'

A topic that was subject to much discussion during the eight interviews was the place of bird painting within the respective realms of 'Art' and 'Science', work habits and approaches to the practice of bird art, and also how the ornithological artists positioned their identities with respect to the labels of 'artist' and 'scientist.' I deal with their comments here in terms of my

initial classification of the artists as ‘Rising Stars’, ‘Mid-Career Artists’, and ‘Gurus’, since the nature of their views appeared to coincide with the degree of career maturity.

#### Rising Stars of the Bird Art World: Dan Lane and Bill Strausberger

Dan Lane labels himself as “a bird illustrator, income-wise” but quickly and emphatically added, “most of my time is taken up with some aspect of tropical ornithology – that is what I do.” His interest in birds and in art began simultaneously and progressed somewhat in concert (Lane earned a bachelors degree in art before studying ornithology in graduate school) At the time of the interview, Lane was still in the early stages of his career as a professional illustrator, although he had achieved some recent notoriety as a tropical ornithologist, aided by his collaborative ventures with the Museum of Natural Science. Still attached to an academic community at Louisiana State University, Lane showed concern about his perceived lack of academic publications, indicating that his self-image is rooted in science rather than art.

Lane realizes, however, that the principal interest of many bird artists lies in narrative painting, and that field plate illustration is considered grinding and generally undertaken in the interests of financial survival: “unfortunately, doing artistic painting is a slow business”. He says that although he realizes he may come to “hate it (field plate illustration) as much as the other people say they do”, that he currently enjoys it and thinks, “it’s kind of fun, its educational... for example, I’ve learned a lot about geographic variation within species doing these Peru plates.” Lane, although having been so far extremely successful, is still early in his career, full of vitality, and regards no bird-associated project as laborious. At the time of interview, he had been a graduate student until a year or so previously, and remains in a frame of mind that values educational experiences over self-expression.

About his relatively few more artistic endeavors, Lane says: ““The closest I’ve gotten in the last few years to really flexing my muscles as an artist is doing hybrid pieces – in between artistic pieces and illustration – illustrating new species for descriptions in a journal, which has resulted in several cover illustrations, and that has been great.” Such plates are narratives in that they have full backgrounds and are shown in natural lighting, but are also intended to demonstrate the important characteristics of the ‘new’ species that establishes it as something different. These are artistic in that they are meant to capture the imagination as well as show the bird, and I enjoy doing that, its kind of fun”. He similarly reports great enjoyment from illustrating travel guides, “where the species don’t necessarily have to be in the cookie-cutter poses popular in some field guides.” This last remark indicates some emergence of the artistic identity, even though Lane is still very much in the mode of scientist, and continuing his own lines of ornithological research.

With respect to his own training in the visual arts, Lane says he learned a great deal in his middle school art classes, and credits a teacher who recognized his interest and “went out of her way to teach me about composition and lighting, and helped train my eye as an artist.” In college, where he majored in art, he found that he didn’t care for abstract art or impressionism: “It’s realism that I really do appreciate Don Eckelberry also taught me about the use of light and shadow, the fine tunings with respect to bird art”, and several people directed Lane to read the letters between Fuertes and Sutton, in which Fuertes explains how light affects the appearance of birds. Lane realizes that he is far from a fully-fledged visual artist: “I am not very refined, I don’t appreciate art in the way that Larry McQueen does, for example. He is well-schooled in art as a discipline and it shows...he knows all the tricks, like how within realism you can use

impressionistic tricks to capture the viewer's attention...other really good narrative artists like Robert Bateman have this ability, too."

Lane says the best education he has had in realism has come from "tracking down other bird artists, studying their work, and talking about it with them personally." He feels that verbal explanations of painting do not translate well, and prefers going to shows to see originals, "look at the brush strokes, and figure out what the artist was doing. The most important way I have educated myself in art is to either figure out what good artists were doing, or to ask them."

The difference between illustration and art for Lane, is that the former is concerned with transmitting information, and that the latter, although it may be instructive, attempts to express the artist's personal conception of the bird and one that is invested with emotion about the organism or scene that the artist wishes to express and share. He stated: "I guess I am a scientist, what I do has scientific merit, but it's all an outgrowth of my love for watching birds - sheer enjoyment is the gist of it. " Science and art are not viewed as dichotomous by Dan Lane; he believes that illustration is so fundamental to ornithology that the images are part of the science and that illustrated field guides and handbooks are essential to the dissemination of knowledge. Lane also pointed out that illustrators have a track record of making discoveries in the process of doing research for illustrations (Lane himself has discovered a new species of barbet in Peru recently, and his colleague John O'Neill has discovered 17 at this point). O'Neill and Pratt also have stories of discovering something that had previously gone unnoticed when studying skins while doing museum research for an illustration.

Lane says that in his own case, the development of interests and skill in ornithology and the visual arts were simultaneous and complementary: "I don't think I would have been a good a



birdwatcher if I hadn't loved drawing them, and I certainly would not have been as good a bird artist if I hadn't been so excited about the subject matter"

Bill Strausberger is unusual among the sample of artists in that although he is very much a scientist, legitimized by a doctorate in ornithology and some twenty publications in the field of behavioral ecology, he is a narrative painter who leans very much toward visual storytelling. He describes himself as a scientist, but his wish to help viewers of the paintings understand the bird subjects as he knows and understands them contains elements of a desire for self-expression that is decidedly artistic: "Bird paintings are science interpreted visually. But I guess what makes a painting 'artistic' is the story that is being told. I want to be a great scientist and a great artist... it is important to me to be accepted by my peers, the scientific community, but ultimately it is people – the general public – who love the beauty of birds. I want to help them understand the birds more."

Elaborating upon his self-concept, Strausberger mused: "A lot of what I do is analytical, but personally, I am very visual, I would describe myself as artistic. But it isn't simple, because my biggest strength as an artist is my skill at observation, and that has been developed by analyzing what I see and noticing subtle gestures, different movements and behaviors. I do think that a real deep understanding of such things is more artistic than analytical."

Strausberger demonstrated more overt ambition than the other artists, and like Dan Lane does not appear to believe that there is an art/science dichotomy: he intends to continue developing as an ornithologist, but hopes that having recently completed his doctoral dissertation; he will have more time to paint. He does not believe that he will be forced to choose between painting and research: "The two are so complementary that it is not going to be an either/or situation." He aims to "paint a book"; a scholarly book on a group of birds, but one

that is simultaneously a coffee-table production of paintings: “a book that is accessible to everyone but that contains information useful to scientists.” The show at NAOC has given him confidence that he can make this vision a reality, since it is the first time he has exhibited his work to a professional ornithological audience.

#### Mid-Career Artists: Eustace Barnes, Jim Coe and Sophie Webb

The energetic and outspoken Eustace Barnes refuses to categorize himself as either artist or scientist, describing himself determinedly as one “who works with Neotropical birds, either as an artist or an instructor or guide.” Barnes stated that he never felt the need to be labeled “‘artist’, ‘scientist’, ‘philosopher’, whatever”, but that he wanted to keep his options open sans titles and labels and trusted himself to be productive and successful. His instructional activities take place in Bolivia, Brazil, Peru, and Venezuela. His artistic activities frequently involve the birds of these countries, and he has also illustrated much of the avifauna of Australasia. Later in the interview, Barnes acknowledged that, “most of my formal training has been scientific” and I never took art lessons seriously, but I could nevertheless do it” Coming from a family of artists (his mother a painter and his father a teacher of sculpture in a British art school), Barnes was provided with an informal training in the visual arts as he grew up.

Barnes takes a pragmatic view of art, viewing painting as a vehicle for the expression of well developed ideas, and not as intended to provoke emotion or raise questions. For this artist, there is no point to having a thought or amassing knowledge if it does not produce action or a tangible product, and any idea of “art for art’s sake” is distasteful to him. Yet neither is he willing to be labeled a scientist: he quite deliberately turned away from a career as an academic ornithologist because in British universities, “I would end up being a scientist with little time left

to paint” whereas now I can use my scientific knowledge to educate people on trips, and to learn more myself, and also produce artwork expressing that knowledge.”

Barnes thinks the entire question of whether wildlife illustration is art is “ludicrous”...it’s fine by me if people want to split hairs and call it illustration, because I am not going to have that discussion. I want to produce paintings, not spend time worrying about “But is it Art?” He was more than willing to discuss the question of the value of ornithological illustration as a scientific tool, stating that the primary importance of illustrations where the avifauna is little known, such as in neotropical birds today, or the birds of north America in the 18<sup>th</sup> century – has/had to be with their scientific and technical components and in raising awareness re conservation of those species and the importance of protecting habitat. This consciousness-raising is the perceived value of ornithological narrative painting to Barnes: “Presumably, paintings of common and non-threatened birds should have some artistic or creative aspect.” And with respect to engaging public interest in birds: “most people would definitely react more favorably to landscape paintings.”

Barnes feels that good artwork in books about birds cannot fail to have an impact on public education and conservation efforts “It’s the most powerful message. It is important that the text is good, but people pay more attention to books with good images.” Paintings convey this message more powerfully than photographs, insisted Barnes, because “you cannot photograph a bird and get the right character – it just can’t be done.” He cites as an example John Dunning’s photographic guide *Birds of South America* (Dunning, 1989), which is “as good a photographic guide as could possibly be but (the images) don’t capture the bird.” Thus photographic images are less satisfactory than paintings because they are not subject to the

perceptions and reflections, of the expert naturalist, and “computer manipulations of photographs do not correct the problem – that is a construction.”

Barnes also spoke of the question of the issue of creativity in ornithological illustration, and where and how this is manifested in the genre. Within a field plate, Barnes believes that considerable creativity is involved in the observation skills and reflecting on what is important, noticing what to include, to convey in order to characterize the species. In narrative paintings, “creativity lies in making the right choices to convey the sense of the bird, you show something of what the bird is like physically, where it leaves and how it behaves, picking the right light conditions, all combined in to a scene you have never actually seen in the field...its like telling a story...putting it altogether and making it aesthetically pleasing. There is definitely a strong creative aspect to that.”

Barnes concluded his thoughts on the place of ornithology imagery within the art/science spectrum by describing how his work habits differ when he is working on field guide plates versus commissioned narrative paintings. He gave this example of how he goes about illustrating a genus of birds for a field guide: “Accumulate as much information as possible: as many images as possible, including photographs, and then combine this information with his my own perceptions of the bird in the field and produce my own drawings. Then I compare my drawings (the finished images of others), and go back and forth, critiquing all of them and making corrections. When I have worked up a series of drawings, I ask myself which are the necessary features for identification and pick the best drawings for that purpose...then I trace the chosen works and paint.”

When Barnes is painting a narrative, he works up the drawing of the bird by the same means, paints the landscape and works his way forward to the bird. He does not do a great

amount of field sketching initially: “I look at the bird for a long period of time...in the Neotropics I would rather spend more time looking at a bird than at a piece of paper while I am trying to draw it. I find that the more time I spend actually watching the bird, the better the results are when I finally come to draw it – however long afterward that is”.

Barnes does, however, make considerable use of video footage and photographs for later use in the studio, and in the field he carries cameras and video recorders to take pictures of scenery, flowers, and fruit that might be relevant to future plates. When he does sketch in the field, “the point for me is to get details down, details I have not encountered in a book, and especially if there is no skin available. And in Britain, there is a lack of skins of the South American birds. If there are skins, I go to the museum at Tring and photograph and measure them. Overall, if I’m sketching in the field, it’s very schematic, recording details, collecting information. I’ll get interpretive and creative later.”

This is quite the opposite approach of Coe, Lane, and McQueen, who believe firmly that they learn to see when they draw. For Barnes, the drawing is a product, an expression of knowledge rather than a means of developing it. His general approach to his work reflects his overall pragmatism; “I am not a perfectionist, my philosophy is to get it done and move on”, an approach to birding and art also echoed by John O’Neill. Barnes is an energetic and productive individual, and has a horror of wasting time. “You can think about things back and forth for inordinate periods of time and at the end of it there is no evidence that anything has moved or changed in any direction. That has no appeal for me whatsoever”.

The second of the three mid-career bird artists in the sample is Jim Coe, who describes himself as a bird illustrator and author of a field guide who has “moved on” to become a “painter of birds in landscapes.” His narrative paintings have a deliberate defining characteristic: they are

produced with the aim of offering the viewer an impression of a happy accident, giving the sense of having captured a quick view of a bird at a particular moment in time.

Coe says he would describe himself as a naturalist and painter rather than as a biologist, although he has a biology degree from Harvard and initially was planning to become an academic ornithologist, until what he saw of faculty life as an undergraduate sent him in the direction of a more freewheeling and autonomous livelihood. “It’s hard to peg it...I am an artist but over the years I have put together a number of different pursuits that work in concert for me at a given time”. He has an undergraduate degree in biology, a graduate degree in art, and continues to pursue natural history interests and computer science on his own, through reading and independent investigation. He displays pride in his ability to support himself as an narrative painter, and is anxious to assert his independence from institutional science: “I consider myself as a well-rounded naturalist more than a scientist, because whatever my background, I am not associated with a research institution...it may be splitting hairs, be a subtle distinction, but I identify more with the naturalist tradition”

However, Coe did differentiate between his work practices for technical purposes, and his approach to his more expressive paintings. His ‘birds in landscape’ paintings represent a developed synthesis of skills. “When I’m out in the field painting the landscapes, I am interested in capturing a fleeting moment of light and atmosphere, and as such I work really fast. My facility with paint is such that I move it around the canvas very quickly and can produce a landscape in maybe forty-five minutes to two hours”. Coe calls his landscapes “happy accidents” that can occur as a result of developed skill in observation and the mechanics of painting, a phenomenon in which he takes profound pleasure: “Its an experience I love.” Rendering birds for his technical illustrations is an entirely different matter: “There I don’t want any happy

accidents, especially in a field guide plate, which is a controlled and preplanned process, laid out well in advance.”

A field plate is a linear process, and Coe says it is frequently two weeks before he picks up a brush. The drawings are made with a fine point pencil, “each feather group very carefully laid out”, then making a template by tracing, and placing each painting-to-be on the board. When he reaches the point of the actual painting, there is little room for improvisation; “it is simply a matter of rendering, filling in the lines and shapes”. When designing a plate for use by relative beginners, Coe remains conscious of the novice eye traveling across the page as it seeks information and makes comparisons: “I am very careful; about creating sequences of shapes across the page, the rhythm of the shape of the birds as the eye travels down the page, and I am most conscious of what draws the eye to figure to figure and elicits comparisons.” When Coe was producing his beginners guide *Field Guide to Eastern Birds* (Coe, 2001), he was interested in broader levels of distinction between genera and common species that are accessible to a novice, thus he chose to leave out certain rarities and uncommon birds that the casual observer is unlikely to encounter, and also eliminated niceties such as age-related plumages of shorebirds, that are difficult for the novice to distinguish even as adults. “Overall, I emphasized shape over profile, the distinctive shape and structure of a species relative to other birds on the plate.”

In contrast to the deliberate and arduous process of creating a field plate, birds in Coe’s narrative paintings are frequently painted in directly, and if he knows the bird so well he feels he has incorporated its character into his psyche, he “starts right in with brushes and paint... I actually feel sometimes, when I am imagining a sketch of a bird, or when I’m working on it, I kind of imagine my hands being the feet of a bird, and how it would sit. And I kind of tuck my arms and my legs and my wings and I kind of imagine this incredible pose... And it’s a strange

moment when it happens and I think this is something that develops when you are out in the field looking at these over and over again.”

Sophie Webb describes her activities as scientist and artist much as Dan Lane does, as emerging and developing simultaneously: “I am a bird illustrator and a biologist...they have always gone hand in hand.” Expanding upon this theme, Webb related her history with respect to both artistic and scientific pursuits: “Well, I drew ever since I was a little kid, I drew animals and wildlife and stuff but when I went to college I actually started off in art school and went to art school for two years and then changed my major to biology and finished my degree in biology. But at the same time I was also taking scientific illustration courses at night, when I was doing my biology degree. Then I took an ornithology class in college and as part of my paper for that I did a bunch of illustrations of bowerbirds, and I did other illustrations for people who needed them, in labs where I was working. So it’s always gone hand in hand, but I think for the first couple of years after I was...after I graduated from college I was working on a lot of different bird projects and I was always drawing, I always had a journal with me but I don’t think I was necessarily thinking of myself as becoming or being a bird illustrator. But I always kept on drawing and doing some watercolors and stuff while I was working on those projects. Then, when that kind of changed really was when I started working on the Birds of Mexico project in 1986. And then I started really painting much more, painting was becoming the major focus, for a while back then.”

Now an experienced field scientist and co-author of a field guide, Webb’s sketching activities are not limited to recording technical details of organisms that she encounters; certain of her Antarctic journals contain lively visual renditions of her colleagues stretched out on bunks, or eating lunch in ice-bound landscapes. However she says her life teeter-totters between



the two activities, rather than integrating the two identities of artist and scientist: “There are periods of time in my life when I am mostly doing biology, and periods of time when I am mostly doing art”

Webb is an accomplished artist whose identity may tend to reside in the artistic realm, because in spite of her fine field skills that keep her in constant demand as an observer of birds on research expeditions, she feels her lack of graduate training in the hard sciences excludes her from full membership in the scientific profession. Sophie feels that women especially need to be over-qualified academically to be considered legitimate in field biology. She acknowledges that most of the excellent career opportunities she has enjoyed have come to her via personal connections, or because she has heard of an interesting expedition being planned, and written to those spearheading the endeavor, asking to be involved. Sophie does not give the impression of an accomplished self-promoter, but her genuine passion and her real skills have in large measure substituted for a lustrous academic resume. She believes that her artist’s eye has vastly improved her skill at field identification and that this has given her opportunities to work on projects where she would not otherwise have been considered competitive without a graduate degree: “If you can paint a bird accurately, people will accept that you do actually know something about it.”

#### Gurus of Bird Art: McQueen, O’Neill, and Pratt

Larry McQueen, formally trained in art as are Jim Coe and Sophie Webb, describes himself quite unequivocally as “an artist specializing in birds” and as one whom science is the servant of art at this point in his development: “The more I work with art, the more I focus on selection of things for the purpose of the art. When I am observing nature, I don’t know if I am being a scientist or not because there a lot of aspects to science that mingle with other areas, and skilled birders are not necessarily scientists where artists definitely can be scientists. But when I

am observing, reflecting, visualizing, I am thinking more of more in terms of painting that I am of scientific information.” It is interesting here that although McQueen positions himself as an artist; he here describes the process of his practice in terms of three critical processes of science – observation, reflection, and visualization.

With respect to the individual development of a bird artist, whether the individual hails from a scientific or artistic background, McQueen thinks there are two contributing factors to the evolution of a bird artist’s style of painting: greater facility with his medium enabling more experimentation, and the continued evolution of his perception: “you continue to see things in a way you haven’t seen before.” This second factor - the constant refinement of perception - is again an important characteristic of the creative scientist.

It is important to McQueen to spend time with other practicing bird artists; “many of whom have had a great influence upon me”. Later, he mentioned a special fondness for Audubon, of making efforts to get to know the work of Fuertes in the Field Museum, and of spending time observing Don Eckelberry at work. However, he does not give too much credence to influence of others. Influences upon a bird artist include “technology, life experiences, other artists” but McQueen was firm that the most important factor in success was the ability and competence of the individual artist, because, “ultimately only you can figure out how to proceed” – a statement that also applies to the majority of research scientists.

Although McQueen has had fun with artwork “making up fantasy species”, he says that in common with almost every other mechanism of making a living – including the practice of scientific research - bird art has a tedious side. This is particularly true of work on field plates “it’s very regimented, requires lots of intense focus on the outcome, requiring lots of breaks from the tension and intensity.”

Producing narrative paintings, “where it is my choice of subject matter, and what to do with it, not to satisfy a requirement or fulfill a certain need” is the aspect of bird art that McQueen continues to find inspiring. “That’s more pleasurable and more experimental...its the areas of experiment that are the most interesting to me...being able to try out certain things and be expressive rather than focused on achieving a desired result”. Narrative painting carries with it a sense of adventure, which is lacking in technical illustration work, and this desire for adventure was also proclaimed by the other self-declared ‘artist’ of the sample, Jim Coe. It may be that those bird artists whose practice includes much fieldwork in exotic locales, such as Barnes, Lane, O’Neill, Pratt, and Webb have their longing for novelty and excitement fulfilled in their travels, and are thus less intense about finding these qualities within their painting practice.

McQueen’s comments did reveal a consistent interest in the scientific aspects of the birds he depicts, nonetheless. He stated that the reward of illustration work is that “while I am doing it, I get a chance to learn more about the animals” and that “drawing is an instructional tool as well as a mode of expression.” McQueen does tend to believe that there is a dichotomy between narrative bird painting and more technical imagery; that narrative work is expressive and field plates are simply illustrative (The Tuftean analysis of narratives presented in Chapter Five of this study does indicate, however, that a good narrative bird painting can accomplish both objectives). Other indications of McQueen’s ‘scientific’ disposition, are that he remains a very active birder (“I do quite a bit of active birding at home, and I never travel without a bird focus”), and spoke many times during the interview of how excited he becomes by new species, new observations, and (on an annual basis) the possibilities of migration time.

Unlike the majority of the artists interviewed here, McQueen is fairly comfortable with the idea of illustrating birds from reference materials such as skins, although he says he needs

some familiarity with related birds in the field to do good work. He also likes to talk with people who know the bird from the field, to get a feeling, “a personalized perception” for it. McQueen records many of his observations with a telephoto lens, but also carries notebooks for sketches and written notes in the field. He thinks of field time as “gathering information” and thus utilizes a variety of methods, including talking with people, and keeping verbal notes on a tape recorder, also used for playback. When he produced field guide plates for the Smithsonian Institution guide to birds of India, he spent a month in the field getting experience of the particular birds he was illustrating, although ultimately he worked from specimens.

Summarizing his comments upon work habits, I asked this senior bird illustrator if having gained expert knowledge of a species as a result of often lengthy and always focused observation that he described, does he then struggle – as an artist - with which aspects of the bird he should convey? McQueen replied that his aim as an artist is to transmit a sense of wonder, reflecting the field experience of “suddenly coming upon the bird and being stunned by the beauty of it in the environment”; “to recreate the process of seeing it in the field”, a goal that involves reflection upon and conscious recognition of the important elements in that magical moment. Even with illustration work, when the painting is more representational than expressive, McQueen “tries to make the birds as lively as I can, and be more than just a design and plumage map of the species”. It is the deep internalized knowledge, born of hours of field observation that gives such an artist this sense of the ‘jizz’, and enables him to breathe life into the ‘map of territory’. Thus without this ‘scientific practice’, the impact of the artwork would be severely constrained. Alternatively stated, without the naturalists’ perception, there can be no sense of the gestalt for the artist to convey.

John O'Neill, arguably the most noted ornithologist of the sample, has also had a longer artistic career than any artist interviewed for this study with the exception of Larry McQueen, and is an extremely successful painter of narratives. Self-described as "a biologist who has painted birds all my life...I guess now I could call myself a natural history artist", scientific ornithology and art have been intertwined for O'Neill for decades. However, throughout the interview, it became clear that his scientific interest in a particular group of organisms (birds) drove the development of his artistic interests, and also that his self-concept is tending to shift from 'scientist' towards that of 'artist.'

O'Neill is the one artist interviewed who firmly believed that there is no real dichotomy between illustration and narrative painting in terms of the artistic content: "the essential concerns are the same...good illustration cannot be separated from art." This artist was eloquent on the subject of the demands of technical illustration of birds, criticizing field guides that are "a little bit too generic" given the recent advances in finer points of bird identification. He gave this example to illustrate how bird art has profited from recent advances in bird taxonomy: "You can tell a Cardinal from a Pyrrhuloxia - which is one of its relatives that's in the southwestern deserts - not only because one is gray with a red stripe down the front and one is red with a black mask, but because they have this completely different look about the face. And I finally realized that in a Cardinal, the bill is fairly normal, in that the upper and lower are pretty much the same size or the upper, the mandible, is just a tiny, tiny bit larger than the maxilla. And a Pyrrhuloxia, the maxilla is fairly unusual in that it is actually a little thicker than the mandible, and it gives it this almost indescribable different look. Bird watchers and artists are now seeing these little tiny things and getting them into their drawings."

O'Neill is also much concerned about the portrayal of the character or 'jizz' that he thinks is evident when the artist knows the bird from field experience. He applies this standard to the artists he is employing in his role as art director for the *Birds of Peru* (Schulenberg et al., in prep.) and also to his own work: "The first plate that I did for this book is of a group of High Andean finches that are principally gray and brown, and I'm just keeping my fingers crossed that at the end there is enough time that I can redo it. The plate that I did is nice, it's perfectly fine but it's not like I would like to have it, because the birds are still a little bit too generic, and I want them to be exactly representative of what genus and what species they are. Both the accuracy, and as the British people say, the 'Jizz' has to be right. I really want people to really pick up this book and say "wow, these pictures are ... these are these birds". And even if the reader doesn't know those birds from the field, they will know what we know about them, because we do know them, we have seen them"

O'Neill holds that illustration demands a skilled and personal observation, it is more than "just reproducing something", it demands skill and an educated and well-honed personal perception, a translation of experience with the bird that is much more than mere reproduction. O'Neill thinks that the users of field guides intuitively know this as well, and those avid for birds realize that more can be learned about a bird from every good illustration that reflects the artist's personal experience with the bird: "Obviously, there is something different in the way that any artist, any given artist puts something on paper. I guess the best example is the number of European or American field guides where you could say to yourself "These are the same old birds." But yet another book comes out, every expert grabs it up and buys it immediately because they know that a different artist, a different author, everything that's different will present something that's not in another book. So in that sense they are learning something from

every new book that comes out. I very definitely think that the same thing illustrated by ten different people is ten different bits of information. Of course, you put down what you see and understand, which may not be what somebody else sees and understands... there is something in an illustration, very definitely, even for the viewer that has the very good knowledge of the same birds". In summary, O'Neill holds that the quality of illustration as art is driven by advances in observation, and by the quality of the perception of the artist, and that the importance of this individual perception qualifies bird illustration as art, rather than skilled diagrammatic reproduction.

O'Neill gave the impression that - unlike the younger artists - he has given quite considerable thought to the question of whether he - as a bird illustrator - is functioning more as an ornithologist or an artist: "I am still deeply interested in research and will do anything to keep the work in Peru going - lots of people are publishing from it, in different areas - but I have evaluated whether I am more scientist or artist" He has concluded that where his life's work has made a contribution is in facilitation of the work of others, referring to the importance of the community of practice to him personally, and as a bird artist: "What I will leave behind is: 1) having facilitated all these other people and making sure that they get this and keep this going and 2) I think that there are far more scientists out there who can publish paper than there are people who can do really nice paintings of birds. So I guess I would say I am an artist, with scientist in parentheses."

O'Neill makes direct reference to the identity shift that I posit occurs in bird artists as they mature in the field: "I still consider myself both artist and scientist, but I think I have made an unconscious - and yet I am conscious of having done so - shift from the science toward the art." He believes that the mechanics of this identity shift have to do with increasing personal

autonomy, and a decrease in a need for approval from the scientific establishment, along with an increasing desire to make a deeply personal contribution: “With the science, you really depend more on the approval of your peers than you do with the art. From the moment my painting is dry I think it gives pleasure to people and I can have twenty paintings that have never been reviewed and show them and someone will appreciate them and like them, whereas a paper has to have the world’s stamp of acceptance. I guess I am leaning a little more toward thinking of myself of an artist.”

Doug Pratt did not describe himself as a scientist at this point in his life, although he is well-regarded in the field of professional ornithology for his revision of the taxonomy of the Hawaiian Honeycreepers, and his extensive knowledge of the avifauna of the South Pacific region. Pratt’s self-description was as follows: “I’m an illustrator, eco-tour leader and musician, anything I can get paid to do and most of it except for music relates to birds. As an occupation in terms of income, I’d list illustrator”.

Pratt takes a utilitarian view of art, “I never thought of myself as an artist in the artsy sense: art was just a tool for me and I did not set out to become a professional bird artist.” He has not had any formal art training, but he does not deny that he served a lengthy self-imposed apprenticeship in the visual arts: “I had to learn to do what I do. I do not see myself as talented; I draw birds well now because that is what I was interested in doing.”

Pratt explained the technicalities and difficulties of field guide illustration at length. Like John O’Neill, he feels that a plate involves as much compositional skill as does a narrative painting, both to fulfill the function of illustrating technical points and comparisons in taxonomy while being attractive to the eye. He also repeated the comments of the other artists concerning the intense focus that is required to overcome the tediousness of being constantly mired in detail:



”My hero, Roger Tory Peterson, used to say that signing a contract to illustrate a book is sort of like receiving a prison sentence.” Pratt explained that the major difficulty in technical illustration for field guides is that a field plate has three aims that are not particularly compatible: “Species A needs to be shown in close proximity to the most similar species (Species B), so the subtle differences are available for visual comparison. However, most field guides demand that species be grouped taxonomically, and the most similar species are not necessarily the most closely related. And often, these two requirements present difficulties in composition – if you get the similarities and taxonomy taken care of, the arrangement can look jumbled and thrown together, or alternatively too regimented.” Trying to account for morphological comparisons and logical taxonomic sequencing while simultaneously composing a plate that invites the eye accounts for more than half the time Pratt typically spends upon a plate.

Pratt feels that field guides are the bedrock of birding activity, and also that those available vary considerably in their provision of basic essential information about species. He admires Peterson’s guide because “the information that is there is very well-organized and predictable. It tells where the bird is likely to be found, then starts from an overall impression and works down to the details, and points out particular features that are salient to the species’ identification. It’s the paradigm for a field guide”

As in the cases of every artist interviewed, Pratt believes that the quality of a bird illustration is ultimately dependent on the illustrator being familiar with the bird in the field. When illustrations are inaccurate, Pratt feels that the problem originates with artists being asked to illustrate unfamiliar birds from specimens and photographs. He says he can spot this with illustrations of birds he knows from the field, because “somebody has missed capturing the jizz.” In his own practice, photographs, videos, and specimens are very much a fallback for him when

he lacks personal experience. He was vigorous and emphatic upon this point “You can’t get around it, there is no way of assuring that you get it right, but some artists do seem to have a better instinct for inferring how a bird is likely to look in life from a study skin, especially if they know related birds” He tells a story of one attempt to illustrate a bird - the Rarotonga Starling – from descriptions alone, when no museum possessed a study skin: “I felt victimized because the information simply was not there – nobody had described what color the eyes were – I had to paint something so I looked at the eye color of related *Aplumbus* starlings and it varied from place to place. So I went with the default eye color in birds, which is brown.”

Pratt laughs out loud at the memory: “When I finally got to Rarotonga, the first bird I saw was the Rarotonga Starling and I swung the binoculars up and thought “It has orange eyes ...practically glowing peach!” So I’m doing a new painting for the next book, and the jizz is better too, its a much rangier bird than I had showed it from the descriptions...but there are occasions when you just have to deal with it (lack of solid information) and hope for the best.” His recently published monograph on the Hawaiian Honeycreepers (Pratt, 2005) is his largest work, and one that took decades to bring to completion following his dissertation research that revised the taxonomy of this group. “These illustrations are a little jazzier than your average field plates, because along with all the historically recorded plumages of Hawaiian Honeycreepers, I included some characteristic vegetation and accessory materials. I feel this is the best work I have done, both for technique and in getting the birds accurately drawn and depicted - I know those birds so intimately.” Accuracy, says Pratt, is the bottom line in field guide illustration; no matter how engaging the plate design, the only real test of quality is the accuracy of the rendition: “It doesn’t matter if Michelangelo painted the plate, if the drawing is bad because it isn’t accurate, the plate is no good” Accuracy in drawing comes from accuracy in observation,

which Lane and Coe find comes from field sketching. This approach does not work for Pratt, who holds that he “cannot sketch” and says that his drawings are “pre-planned and schematic productions. My sketchpad is the camera and it is much more efficient for me...I am not a field sketcher, I think that is one place where an inborn ability, or talent, exists.” For years, Pratt says he doubted his own competence as an illustrator due to his lack of ability at freehand drawing, but Don Eckelberry reassured him “that there is no rule except what works, and I have found a combination of approaches and techniques that work for me.”

Pratt finds his scientific background – he possesses a doctorate in ornithology – to be the key to his success as an illustrator, providing him with greater understanding of the bird when he approaches a painting: “I prepared so many specimens, taking birds apart and putting them back together, I developed a feel for how parts of a bird work together, how wings fold in flight and how different feather groups lie.” He finds this literal “hands on” knowledge especially valuable when he has to work from photographs, believing that there is a certain knowledge that is transmitted to the brains only through use of hands and eyes working together, to get that ‘feel’ for the organism. Particularly in this field, he recommends that would-be bird artists volunteer their services in skinning and specimen preparation. “You not only learn how a bird is put together, but you learn how bird specimens are made and automatically can reverse engineer from bird skins to visualizing the live bird. The problem with painting from specimens is that live birds do things with their plumage; the feathers on the skin do not end up in the same place on a live bird.”

Artists also have to learn that feathers have an aerodynamic twist, more akin to an airplane propeller than a two-dimensional object. Pratt points out that beginning bird artists tend, for example, to treat tail feathers as a fan, or deck of cards, whereas “in reality, there are no

straight lines on birds. Yet beginners draw feathers as straight lines all the time...putting a feather on a table corrects that impression”

Technical knowledge of birds can sometimes cause problems in interpreting images. Pratt has battled with consultants hired to review the quantitative correctness of his illustrations in field guide, especially with respect to wing measurements. Ornithologists would apply ratios found on the bird to the illustrations, “without taking into consideration that perspective changes everything and wings do not come back as straight lines from the bird’s shoulder to the wing tip – they will curve away from or toward the observer depending on the angle.”

He agrees that drawing/sketching improves observation, and had his students draw during his years as a high school biology teacher: “that (drawing) makes you see things that you wouldn’t pay attention to otherwise.” He found learning to draw difficult, and because of that difficulty feels he can teach others to draw “or at least to copy...but its like pulling teeth sometime, getting people to disconnect from “I can’t draw” and their familiar ways of seeing.” Drawing apart, Pratt says that he would expand upon students observational capacities by literal hands-on experience with organisms: “I’d get a bushel basket of something expendable like poisoned starlings, to have dead birds available to manipulate, the wings, tail, and bill, *to see with the hands* how a bird works. Having the bird in your hand is important.”

Pratt gives the example of otherwise competent artists who show a bird singing with the head back and the bill open “They extrapolate to mammals and make the bill open like the letter V...whereas a bird’s lower mandible has an extra bone that connects it to the skull so it swings free and moves forward and backward which a mammal jaw can’t do, and it also means that that the open jaw doesn’t hinge from a single point, it has got another thing in there so it makes a big

arc and drops down a little bit. That is a common mistake, especially with beginning bird artists. And that's just a matter of knowing the anatomy, of knowing how it works."

Pratt thinks that those who have a talent for drawing tend to gravitate toward the more creative aspects of the visual arts, and would lack the degree of patience that illustration requires: "It's tedious and confining and drives such people crazy. Whereas somebody like me, I find the anal-retentive aspect of it appealing. But I'm not of the sketcher school." He acknowledges the varied approaches in bird illustration based upon the different talents of individuals, such as how Fuertes would spend all day just looking at birds in the field and return home to paint them from "an incredible photographic memory. And I have never and will never have that". Lacking visual memory or natural talent for drawings, Pratt's particular ability arises from a willingness to acquire knowledge constantly, and to persist and revise. "I have sufficient accumulated knowledge that I can produce a good drawing even if I can't draw...by wearing out erasers and drawing pieces of the birds over again until it looks right."

Narrative painting or "decorative stuff" is more attractive to Pratt than field guide illustrations, and he thoroughly enjoys private commissions for such work, but he is an essentially pragmatic soul. Illustration work is secure and relatively well-paid, and he feels this is an area where he is extremely competent, by virtue of both experience and temperament: "A lot of bird artists –especially real artists – simply don't have the patience to do field plate illustrations, especially the clinical 20 birds—per-page in- the- same –pose type of thing. If they lack the necessary patience, they are not good at it." Pratt admires Robert Bateman as one of the greatest narrative bird painters, but "I don't know if he has ever painted for a field guide in his life, and I don't know if he could do a plate." Unlike his friend and colleague John O'Neill, Pratt appears to be one artist who believes there is a definite schism in bird art between

illustration and narrative painting. O'Neill offered the opinion that Pratt holds this belief in part because he has yet to turn to serious narrative painting from his illustration work. Both Dan Lane and O'Neill believe Pratt to be a superb painter of narratives, but he chooses at yet to work only occasionally in this genre. One explanation for this choice may be that unlike the other 'gurus' of bird art interviewed here, Pratt is also active as a performer of music, and thus has another outlet for self-expression.

### Theme #3: The Nature and Development of Expert Perception in Naturalists

The developed naturalist intelligence is defined by Gardner (1999) as an extensive knowledge of the living world, and in the expert recognition of plants and animals of environments familiar to the naturalist, who has developed the ability to distinguish between species of organisms, and perceive relationships among those species. All of the ornithological artists interviewed for this study had spent much of their lives in intelligent and aware perception of birds in their natural environments, and this expert perception was much in evidence as they described their work.

Much was said by each of the participants about the central role of observation skill in their practice; the refinement of perceptual skill that is the combined result of an expert knowledge base interacting with years spent in the field watching birds. Eustace Barnes was direct and eloquent upon this point, stating that a 'creative' naturalist has educated observation skills that go beyond the visual: "a photographic memory does not mean that one can assess a bird." Barnes reports sometimes hearing vocalizations of a rainforest species years before he sees it, and has to work out how to track the bird down in order to achieve even a partial glimpse of it. If the bird inhabits high canopy or dense vegetation, he then has to construct a whole

image of the species from these momentary and partial glimpses, along with cues obtained from behavior and the habitat.

Barnes believes this ability to be a generic characteristic of skilled naturalists: “The bird does something, flicks its tail or a wing and instantly you know what it is...A field biologist with any creative capacity can take in details quickly, memorizing forms and postures and putting information that has already been internalized to use. This skill of snap identification, even from a subtle behavioral cue or a new vocalization is pretty widespread among expert field naturalists.” Barnes’ previous knowledge of other bird species is expertly applied here, supplying some educated preconceptions about the unknown species – an expertise founded upon fluent retrieval of an expert knowledge base.

In Barnes’ long experience as a birding group leader in the tropics, he has found that not everybody can achieve this level of skill given the requisite education and experience: “Some people just can’t do it, no matter how many times they have seen the birds, or the features of the species have been explained to them. There has to be a conceptual key in the mind that can take account of and classify subtle and specific differences between species. If the basic ability is not there, a person is not going to be able to make difficult identifications because it is beyond mere observational skill.”

John O’Neill’s description of his own expert perception of birds also supports Barnes’ presentation of a skilled and fluid interaction between the knowledge base and a trained observation. He emphasizes the intimate knowledge of an organism that enables a Deweyan style ‘seeing’ with true understanding: “The naturalist has to learn to see, not just to look; there is a definite specialized thought process attached to this...” O’Neill cites as an example how for many years he puzzled over the difference between a cardinal and its Southwestern desert

relative the *Pyrrhuloxia*, until he realized that a minute difference in the ratios of thickness between the mandible and maxilla in the two species gave the “intangible different look about the face” that he had struggled to explain.

This senior illustrator spoke eloquently and at length about the development of expertise in field ornithology: “You have to know the little things as well as the correct anatomy. You need to study the organisms, to hold dead birds in your hand and really, really look at them – it doesn’t hurt to do a hundred sketches of one bird from different angles. But above and beyond anything, be a watcher of birds. Look at birds, because that is where understanding about behavior begins, and then understanding about how different behaviors and actions affect the bird’s anatomy. Study bird feet at the feeder; that’s sort of dull but one really begins to understand the bird. You need to learn to see, not just to look, and then you can begin to understand the anatomy and the behavior and how they work together.”

Doug Pratt also elaborated on the knowledge underlying the expert perception of these organisms, speaking of the importance of understanding the basic form of feathers, and the biomechanics of the bird that come from much literal “hands on” experience. “It is getting up close, literally having a bird in the hand, that allows anatomical knowledge of the organism to be internalized. Pratt echoes O’Neill in insisting upon the importance of touch – via skinning and dissecting – to remove the ornithologist from the role of distant observer.

When I asked Pratt to reflect upon his thought processes as he first observes a new species of bird, he implicitly referred to metacognitive processes and questioning his own expert knowledge base, similar to Barnes’ conceptual key: “Ideally the unknown bird should be positioned within a nested set of categories, size, Passerine or non-Passerine, thrush-like or warbler-like, forming as many categorizations as possible and continually making comparisons



with species that you know.... You winnow down everything, starting with what is known, then go to a field guide or expert with what you do know and don't know, what you have and have not been able to classify. I constantly ask myself, "What do I need to know about this bird?"

Pratt went on to stress the importance of observing and interpreting the bird's behavior, once the anatomical features have been classified with reference to pre-existing knowledge: "If it sits on a branch, how does it move around? Does it cock its tail, let it droop, or keep it in the same plane as the body? Does it sit upright or crosswise on the branch? How much does it fluff up its feathers, and why...is it simply dependent on the temperature? You need to know all these things to know the bird, to have familiarity in an anatomical, ecological, and behavioral sense"

Pratt concluded his thoughts on expert perception by saying that this was always based upon an unusually high degree of sensitivity to the environment: 'It is important to be attentive, not only to things like the presence or absence of wing bars, but also to sounds in the environment. I have been in a hotel room with a group of birders, going over what we had seen that day, and heard a Barn Owl. The group heard it too, but they paid no attention until I pointed it out. An expert birder has senses set at a high level all the time – they are not just turned on and off.' This state of sensory 'red alert', combined with an expert knowledge base that assists educated seeing, produces an 'instinct' for the identification of birds and for the relationships between them, a feel for what is likely to be present in a given situation – much as that described by Barnes. Pratt says this seems like an almost magical ability to the uninitiated, but he identifies the phenomenon as nothing more than an unusually high level of expertise, the fruit of "processing more information than other observers, and missing less"

Larry McQueen attempted to explain this perception of the expert naturalist in terms of knowledge of the aspects of a phenomenon that the observer should attend to: "There is a

definite commonality in how birders look at birds, but the expert ornithologist is not so concerned with seeing a full range of species in a given habitat, but will focus on other aspects, will seize the moment to focus upon an obliging bird, will take full advantage of the bird that just happens to be sitting for a while, to take advantage and thoroughly study it. And if you want to focus upon a particular species, you have to work out where to find it and to follow it around. You live with a bird and find out as much as you can. You have to appreciate the bird as more than a plumage map, that it does different things with its plumage. You have to understand the character, the particular liveliness that is part of seeing a bird in the field, and at the same time note the little details like the skin color around the eye.” McQueen believes that taking in so many aspects of a bird and making sense of them is an ongoing developing ability that improves over a lifetime in the field, stating firmly that his own perception “continues to evolve with maturity.”

Jim Coe, who quietly insisted that he be described here as a naturalist rather than an ornithologist, since he has no institutional affiliation designating him a scientist, takes the deepest view of all of the developed naturalist intelligence. While he echoed the statements of other artists regarding the development of snap identification skills, finely tuned senses, and an expert knowledge base, he took the depth of understanding of a species to a rather different level. On looking at familiar birds, Coe seems to go a little deeper than mere recognition of species, using his trained artist’s eye to allow the bird to assert individuality: “Every bird has a combination of expression, pattern, and shape that makes it unique...I call it personality...I look for that when I am seeing a bird in the field.” This recognition of individuality again calls for an expert knowledge base, drawing upon subtle characteristics from mental images filed away in memory, an understanding of the species and the realm of possibilities that exist for its

movement, posture, and expression. Coe, however, was somewhat discontented with this dissection of his artist's vision: "I prefer to think of this depth of understanding as beyond knowledge, something more spiritual, like a real kinship."

All eight artist-naturalists interviewed spoke at length on the subject of how long hours in the field and highly tuned observation skills combine to provide a knowledge base that then enhances the quality of subsequent field experiences. The three 'gurus' of the sample – McQueen, O'Neill and Pratt – and two of the mid-career artists – Barnes and Coe – have been quoted extensively above on the importance and character of this skilled perception of the expert naturalist. The younger artists – Lane, Strausberger, and Webb – likewise emphasized their skilled perception, and spoke fervently of the time and effort necessary for the ongoing development of this ability.

Sophie Webb recalled that during the time she was working on her first major field guide, a handbook to the birds of Mexico and northern Central America, she would travel those countries for months at a time, simply looking and sketching, collecting and recording small details visually, then repeating the exercise in a different region to determine if these details varied between regions. She considers it of paramount importance to spend adequate time collecting information on the full array of anatomical variations and behaviors of each species: "You do not necessarily see what the bird is like at first...you have to spend enough time in the field to get the overall character. You might see it initially sitting horizontally, and later realize that ninety per cent of the time it sits straight up with a cocked tail, or that it appears fatter or skinnier depending upon how it is moving.'

Sophie constructs her final internalized notion of a bird in a very systematic manner. She has an impressive array of loose-leaf notebooks, videos, and art portfolios that together

document her total field observations of that species. To refine and integrate her understanding when the time comes to paint the bird, Webb will assemble all her field materials in one room, putting notes, sketches, and photographs on bulletin boards, and simultaneously playing video and audiotapes.

Dan Lane echoes the same sentiments as Webb and Strausberger with respect to the importance of taking the time to develop a deeply personalized feeling for the organism, that manifests as expert perception: “I spend the majority of time in the field, taking notes, making sketches, sound, and video recordings, and most of all just looking...observation plays a huge role.” His preferred mode of recording his field experiences for later reflection is drawing: “I carry my sketchbook wherever I go in case I see something that I haven’t seen before or that might be important later...my drawings lead me back to my memory of the bird, the observations I made that I forgot to note down, and also how it behaved...the drawings are a personal connection back to the original experience of being with the bird in the field. Then I do my own mental editing of what is important, paring down the whole experience to the gestalt of that bird.”

Lane also refers to the importance of continually developing the expert knowledge base in order to maximize the value of important field experiences. Describing a particular observational triumph of his early career – discovering a new species of barbet on his very first South American expedition, he reports how internalized knowledge allowed him to identify his find: “I spent about two hours being the only person in the world to have seen that bird...I had given up the day before to studying all the field guides, I knew exactly what species of barbet there were in the world, and that this didn’t fit the description of any of them” Thus educating his perceptions has had considerable personal and professional rewards for Lane, but in common

with the other artist-naturalists discussed in this study, such skill has required a tremendous investment of disciplined time and energy. When asked to comment on what fueled the drive behind such commitment, Lane replied with no hesitation, and spoke clearly and energetically in terms of biophilia: “Studying tropical ornithology is what I love to do more than anything else...I have this inherent interest in birds. I have always been a bird watcher and my life grew from that. My work has scientific merit, I guess, but it has always been about sheer enjoyment. I love watching birds.”

#### Theme #4: Heroes, Role Models, and Mentors: Individuals and Influences Upon Development of the Bird Artists

One major theme that emerged from the interviews that appeared highly relevant to the development of the naturalist intelligence is the importance of childhood heroes and role models in providing inspiration and in “showing the way.” These figures were generally ornithologists and bird artists of some reputation, who became known to the incipient naturalist – frequently via their publications – at an early age. The participants collected articles, books, and reproductions of their paintings by their heroes, and in some cases went to great lengths to establish personal friendships and mentoring relationships with these experts. Informal apprenticeships were often initiated by early adolescence: others took shape during college years. Even after graduate school, these participants continued to attach themselves to a series of ‘masters’, either in the field of ornithology, or in natural history illustration.

As biophilic tendencies and the naturalist intelligence combined in these budding naturalists, the reinforcement of values and the development of skills and knowledge were provided by a variety of sources. Support for their values, visions, and ideals, in addition to practical assistance with skill development and professional and educational opportunities came from books, artwork, and institutions, in addition to key individuals. In the early years, these key

individuals tended to appear as family friends and neighbors who were willing to spend time and share their birding expertise, helpful members of local bird clubs, and encouraging school teachers. Eustace Barnes received no direct support of his birding activities from his family as a child, but was encouraged and supported by a family friend; “a very valuable educator who had a general interest in the sciences and would take me out and show me things.” James Coe had peers in his neighborhood with parents who were interested and knowledgeable, and went exploring, birding, and sketching with these friends. Dan Lane was introduced to a local bird club by a neighbor at the age of eight, and this group provided opportunities for local travel to birding spots, instruction, and a variety of contact with experts that he made full use of as his interest and skills developed. Lane also credits a middle school art teacher with training his eye and refining his observation skills. At twelve years of age, John O’Neill and Larry McQueen were also keen members of local bird clubs. Sophie Webb was enrolled in the Audubon Summer Camp every summer from ages seven through twelve, and year after year found that the nature activities and projects reinforced her interest in and knowledge of, natural history.

In addition to this social support, some participants also reported that as elementary school children, they were influenced and supported by books, magazines, and artwork about birds, and even natural history programming on television. Doug Pratt owned the first edition of the Peterson Field Guide to Birds, which he says, “was my bible as a little kid,” and regarded the author and illustrator Roger Tory Peterson as a personal birding guide, friend, and hero. O’Neill owned the same text, which stimulated the development of his interest, and at age nine set himself the task of memorizing all the images in the book. McQueen was “inspired as a child” by Audubon’s *Birds of America*, a gift from his parents, and recalls haunting bookstores and libraries in search of more illustrated bird books from which he could learn more. James Coe

also studied field guides at home between birding trips, to elaborate upon previous sightings and to clarify his ideas about what aspects of birds to concentrate upon. A subscription to *National Wildlife* magazine fed Coe's growing appetite for narrative bird paintings and introduced him to the work of Don Eckelberry, later to become a significant personal mentor. Sophie Webb not only had a treasured collection of natural history books, but mentions that visits to the Peabody Museum, and natural history television programming were important in stimulating, developing, and maintaining her passion for the natural world.

High school was also a time when these fledgling naturalists became aware of the existence of professional illustrators and established bird artists, and were frequently given help and support by these senior naturalists. In particular, Coe, Lane, and McQueen fell under the tutelage of Don Eckelberry, and George Sutton assisted both O'Neill and Pratt at different times. Coe had admired Eckelberry's work in *National Wildlife*, and with the encouragement of a high school teacher, wrote to this artist, resulting in an invitation to visit Eckelberry's home for help and advice. Lane followed the same course after being provided with Eckelberry's address by a counselor at a bird-watching camp. Eckelberry provided critiques and tutoring for both Lane and Coe via personal visits and mail, and in addition to the improvement in skill and knowledge that resulted, this contact provided an important personal validation for the young men's self-concepts as artist-naturalists. Bill Strausberger reports a similar experience when a high school biology teacher who was pursuing her own doctorate at the time encouraged him to think in terms of ornithology as a career, and assisted him with finding a funded place on a research trip to South America. This teacher not only affirmed bird study as a worthy life-course for a mid-western farmer's son, but "she really opened my eyes to science, that people could do bird research as a career."

After high school, the role of college teachers naturally became increasingly important. In his last year of high school, John O'Neill had contacted George Sutton, an extremely well-known bird artist who was also a professor of zoology at the University of Oklahoma, and this 'hero' encouraged O'Neill in his birding and artistic pursuits throughout his undergraduate years, providing critiques of his paintings, advice, specimens to observe and paint, and fieldwork opportunities that were usually reserved for graduate students. Doug Pratt was steered to ornithology as a life-course by a favorite botany professor at Davidson College, who noted that on field trips Pratt spent more time looking through his binoculars than at plants. Pratt says: "I really had no idea that I could make a profession out of what I loved so much – birds – until this favorite professor who was something of a mentor said I would be crazy to become anything other than an ornithologist." Pratt, who was at that time planning on becoming a teacher, has never since looked back in his ornithological career, and this moment of validation from a respected professor was remembered for decades and seems to have been pivotal.

Sophie Webb was also provided with this all-important direction from her undergraduate advisor at Boston University. After changing majors from art to biology, because "I couldn't stand the idea of not being with animals," Webb was floundering in the curriculum, with a cell biologist as an advisor, and felt discouraged and "totally overwhelmed" with her courses. When a family friend directed her to a sympathetic faculty member in ecology, who was supportive and made time for her, "I felt I could continue on in biology, I worked at the New England Aquarium and took courses, I did field studies of birds and took illustration courses at the Harvard Museum of Comparative Zoology at night..." Nearly twenty years later, Webb still remembers this advisor with palpable gratitude and relief: "He was just a wonderful man, always had time for his students, he gave me tons of advice, he was kind to us, he was just great." This story illustrates



the importance of an encouraging mentor in finding a life direction, or simply the courage to switch directions or summon the fortitude to stay with a chosen course, even in such determined and self-directed individuals as the participants of this study. James Coe recalls being actually turned away from his original plan to pursue graduate study in ornithology and being redirected into an MFA programs by the examples of two young faculty members at Harvard: “One of whom I’m sure is totally unaware that he pushed me away from science simply because he was a role model, and I felt he presented a pretty good clue as to what was in store for me if I became a scientist. I could see myself as an associate professor at some university and I ...he was very young, was only a few years older than we were and I didn’t like what I saw.” Coe went on to speak of the narrow and driven life that he perceived, and continued: “At the same time I was being pushed away from academia as a career, I was pursuing a drawing course with a very charismatic artist. He had a much more interesting and exciting life and I think that those two influences working in concert turned me around and made me think of art as a primary pursuit, and I became less interested in pursuing graduate school in the sciences. There are always things – usually people – who even unconsciously push you in different directions. This change of direction was evidently fortuitous for Coe, who now enjoys an entirely satisfactory life as an independent naturalist, author, and painter.

A number of participants also retained contact with bird clubs, and initiated contact with professionals in the ornithological community who were later to prove key figures in their own professional development. John O’Neill became involved with the Cleveland County birding club during his undergraduate tenure at the University of Oklahoma, where in addition to continuing to expand his knowledge, two members invited him to accompany them to Peru for a summer, a trip that effectively initiated the direction of his eventual career in Neotropical

ornithology. Doug Pratt also visited events sponsored by different bird clubs in his undergraduate years, one of which led to a meeting with painter George Sutton, of which Pratt says, “this was a brush with greatness from which my entire career (as a bird painter) dates”, for he then had the opportunity to inspect Sutton’s original work, an experience that he claims immediately improved both his bird observation skills and his painting. Barnes studied general ecology and biogeography in a British University that did not offer specific ornithology studies, but maintained his passion for birding and refined his specific skills with birding groups outside of the university. After graduating with a bachelor’s degree in biology, and then an Master of Fine Arts in painting, Jim Coe was floundering professionally, and his membership of a Central Park birding group inspired and encouraged him to produce his first field guide.

After graduation, a number of participants cite institutions as playing both an inspirational and nurturing role in their professional development. The Museum of Natural Science at Louisiana State University has a vigorous and well-developed tropical ornithology program that provided mentors, contacts, and instruction in both ornithology and natural history illustration for O’Neill, Pratt, and Lane. Sophie Webb pays homage to the encouragement and help she received from both the American Museum of Natural History – who gave her free and ample access to their specimen collections – and the Point Reyes Bird Observatory in Marin County, California, which provided initial internships, research opportunities, and a literal cabin home for her for many years.

Established bird painters continued to play a significant mentoring role as the participants developed their own professional lives. This role sometimes involved proffering instruction and professional opportunities, and was sometimes significant merely from the example and inspiration provided by senior illustrators. Eustace Barnes mentioned that personal contact with

British wildlife artist Clive Byers played a role in encouraging him to finally leave teaching to become a professional painter; Jim Coe states that his personal heroes Larry McQueen and Lars Jonsson enlarged his ideas of what bird painting could be at its best, and continue to be instrumental in forming and sustaining his vision. McQueen describes haunting the Field Museum to visit with and seek inspiration from the works of Louis Agassiz Fuertes, and seeking out Don Eckelberry to see his original work and learn how this admired painter worked. Long after his own professional reputation was well-established, John O'Neill found continuing inspiration in the works of Robert Bateman and Bruno Liljefors, whom he says set a standard for wildlife art that O'Neill himself continues to aspire to. Pratt stated that his seminal dissertation work on the Hawaiian honeycreepers was validated and driven by the encouragement of prominent ornithologists John Bowles and Sherman Colquist. Sophie Webb, who eventually elected not to pursue graduate school, and suffered some self-doubt regarding her ability to make original contributions to the field as a result, cited other non-academic bird artist such as Ken Kaufmann and David Sibley as providing reassuring role models for her.

#### Theme #5: The Importance of Communities of Practice and the 'Invisible College' of B Art Practitioners

Illustrating birds, particularly outside of an institutional setting, results in an isolated life-style, with little structure or system of rewards or recognition. Thus the bird artist tends to lack social and professional support, and may particularly feel the need for validation of his or her work and values. Scientists – although characterized by independent personalities and placing a high value upon autonomy – frequently engage in extensive collaboration. A strong association between colleagues serves to concentrate energies, and results in greater productivity and more recognition than is achieved by the individual who works alone (Price, 1963). Crane (1969) hypothesized that an 'invisible college' tends to become established among individuals pursuing

remote and specialized areas of science; that is, a network of intense relationships and patterns of collaboration develop between scientists who may be institutionally and geographically remote from each other. A semblance of this invisible college appears to be provided by an informal community that has emerged among the practitioners of bird illustration, providing practical support in ornithological matters and painting techniques, occasional professional opportunities, some social support, and validation of a worldview and choice of life-style.

Six of the eight participants in this study made use of such a network, although the rewards that they reaped from this varied with the individual and the career stage. The two exceptions were the British painter Eustace Barnes, and the newcomer to the bird art world, Bill Strausberger. Barnes, who spends the majority of his time in the South American rainforests, well outside the reaches of most social opportunities, mentioned other illustrators only very infrequently during the interviews, and implied that this community of bird artists is a cultural artifact of American university and museum circles, and does not exist in the United Kingdom, where ornithology is predominantly an amateur pursuit. Strausberger is aware of the existence of community among more established painters, while also realizing that at this time his work has not been sufficiently widely circulated to come to the attention of the gatekeepers of this community. His first major show occurred shortly before our interview, when he displayed five paintings at a bird art show at the 2002 annual meeting of the North American Ornithologists Union. He was grateful for the input he received from other artists, and felt reinforced in his ambition to produce his own illustrated book on aspects on bird behavior. He also realizes that he needs to become a more established part of the bird art community to make this vision a reality, because “I don’t quite know how to go about it at this point...I need to make some friends.”

Like Eustace Barnes, Jim Coe practices his profession as a relative 'loner', operating outside the circles of academic ornithology and research. He knows many other bird painters socially, however, and values the exchange of ideas and validation that such contacts provide. He speaks enthusiastically of a tradition of an annual weekend get-together of artists, begun by master-mentor Don Eckelberry ten years ago, and continued by leading wildlife artist Al Gilbert. A number of artists gather at Gilbert's house for a weekend, go out birding and sketching, and show their work: "And there's usually about twelve artists every year, not always the same group, although there is a core, and it is a wonderful experience every time, everybody leaves fully charged to go back to work. We have really created a community for ourselves. It's so hard to find other people who do the things, the kind of work that we do, and we all feel so isolated in our distant little worlds. It's a way of coming together and then maintaining a community during the year. We talk to each other or communicate via e-mail, and we all look forward to this time when we meet in person"

Sophie Webb occupies a more central position between the art world and that of academic ornithologists who have moved to bird painting as a primary profession. She did not attend graduate school, yet has occupied a number of temporary field research positions that have resulted in significant institutional affiliations that confer some sense of community. Since she embarked upon her painting career, she says her continuing attendance at American Birding Association conventions (where she frequently leads workshops and gives talks upon her travels), provide her with social and professional contacts among other bird painters who attend. Sophie also acknowledges a sense of community with the ornithologists and illustrators at the American Museum of Natural History, where she has spent many months conducting research among the bird specimen collections.

Sophie was at great pains throughout our interview to acknowledge the help she has received from other ornithological artists. Well-established bird painters Al Gilbert and Guy Tudor have loaned specimens and photographic materials, assisted her with technical details, and provided encouragement and direction when she was in uncharted territory professionally. More recently, she met John O'Neill at a professional meeting, and this friendly though exacting 'guru' has provided her with some mid-career professional mentorship, offering her assignments for his *Birds of Peru*, and loaning specimens. Like James Coe, Sophie is a regular attendee of the annual bird artists' weekend in the Northeast. She is a friend and great admirer of Coe, and a plate of his sparrows, a birthday gift from her family, is her "most treasured possession." The bird art community also serves as a source of validation and reassurance for Webb, who is concerned that her lack of a graduate degree will detract from the perceived value of her work, and she particularly values the success of other bird artists and ornithologists who have eschewed an academic career path yet still made a contribution to understanding and depicting birds, such as Jim Coe, Ken Kaufmann, and David Sibley.

Finally, other bird painters appear to provide vision and inspiration for this mid-career illustrator, and stimulate Webb toward perfecting her own style. Of a recent contact, Robert Verity Clem (illustrator of *Shorebirds of North America* (Matthiesson, 1967), she says, "I realize that sometimes I overwork stuff...his little field paintings were so light, so fresh, they were just beautiful..." Such encounters recharge the painter's batteries, particularly in the midst of onerous commissions, and this meeting resulted in Sophie beginning a new quest for more surety of vision in her work.

The four artists in this study whose work was nourished by strong ties to the scientific ornithological community were John O'Neill, Doug Pratt, Dan Lane, and more peripherally,

Larry McQueen. These four individuals were linked by a common connection with a particular center of ornithological research, that of the Museum of Natural Science at Louisiana State University. It is not unlikely that other such informal communities are centered within other research settings at other large universities and museums.

John O'Neill finds ongoing support in discussing birds and art with Doug Pratt and other resident and visiting bird artists – including McQueen – at the museum. He meets the wider bird art community at ornithological meetings and more specific social events, such as an annual bird artists' weekend accompanying a show of work sponsored by the Leigh Yorkee Woodson museum of art in Wisconsin. An acknowledged contemporary master of the bird art genre – as illustrator and narrative painter – O'Neill has developed a strong commitment to mentoring younger naturalists and bird painters, stating explicitly that he wishes his career legacy to be advancing the work of others: "What I will leave behind is having facilitated all these other people and making sure that they get this (become good observers and painters) and keep this (tradition of excellence in bird art) going."

Pratt and Lane have both been recipients of O'Neill's advice, tuition, and career mentoring over their years at the museum. His standards are exacting when commissioning illustrations for his own publications, but he appears to enjoy finding work for others, and matching the work to be done to the particular talents of the artists. On his upcoming large project, a definitive handbook to the birds of Peru, O'Neill has employed Pratt, McQueen, Lane, Web, and twelve other artists from an extensive network of colleagues around the world. At a less elevated level of mentoring, O'Neill also gives time to teaching in the local community, offering a class or two every year for aspiring bird artists at a city recreation center in Baton Rouge.

Pratt stated that although prior to his association with Louisiana State University, he had “picked up a lot of information from bird artists I knew in the Carolinas”, a few months working under the tutelage of John O’Neill enabled him to leap from mere illustration (“simple diagrammatic stuff”) to narrative painting as he gained confidence in his visual insights and learned to transmit these via his artwork. As described previously, O’Neill also initiated Pratt into the community of senior bird artists, resulting in his first major commission as a field guide illustrator. The LSU community also facilitated Pratt’s introduction to Hawaii, other institutions (the American Museum of Natural History and the Brigham Young University in Hawaii) provided mentorship in the form of financial support for his dissertation research there, and Pratt is now a leading expert on, and illustrator of, Hawaiian avifauna, and is socially entrenched in a network of Hawaiian ornithologists.

At the time of the interviews, O’Neill and Pratt both remained upon the staff of the Museum of Natural Science at LSU, and had been friends and colleagues for more than thirty years. Although Pratt says he owes much of what he knows about bird observation and painting to O’Neill (who in turn credits other artists with the same), their specialized interests in ornithology, and their respective styles of painting, are quite different. However, they both remain completely absorbed by birds, the problems of ‘seeing’ birds, of interpretations of observations and of translating these perceptions onto a two-dimensional surface with paint. They remained joined by their shared values and worldview. Pratt recounts a typical conversation as they strolled across the LSU campus: “John and I were walking across campus, there was some shrub in bloom, we were talking about something – probably birds because that is all we ever do – and he said, “I know what you are thinking about...you are thinking about how to paint that shrub” Pratt insists that is a typical example of the naturalist mind-set: “You



can't do anything without looking at birds and plants...you are in a constant state of sensory overload, a state of red alert."

Other bonds between the two artists have become forged as a result of shared mentoring activities with younger artists. For example, the two 'gurus' have one very successful joint protégé – Ron Louque – who on graduating from LSU became a professional wildlife artist and won the prestigious Duck Stamp Competition in 2002. Pratt recalls fondly how as an undergraduate, Louque would haunt the museum to watch the two senior artists at work: "He would practically perch on our shoulders...he wasn't bad when he left us, and I understand he does superb work now."

Dan Lane is also somewhat a product of the bird artist community of the LSU museum. Graduate school friendships remain important to Lane, and he regularly communicates with and visits a group of internationally based ornithologists who were his peers at the museum during his studies there. He speaks of the high-profile scientists who were his advisors – John O'Neill and James Van Remsen – as people he continuously seeks to model himself after, and of how the bird-oriented community of the museum remains a significant source of inspiration to him: "My having been here has allowed me to meet some really incredibly ornithologists – I am constantly amazed and humbled by how much they know." The ornithologists with whom Lane continues to associate at the museum frequently ask him to illustrate their technical papers, and his former graduate advisor (Van Remsen) is planning to utilize Lane's skills illustrating a field guide to the little known birds of Bolivia. Lane values his formal education at LSU, but says that his real education in bird painting grew of his efforts to connect with admired practitioners in the field, both by studying their original work and during the course of long and intense personal conversations. He does not believe that a bird artist can develop his or her talents independently

of such a community: “None of this is done in a vacuum; you are always building on the experience of others, relying on their advice and studying what they do.”

#### Summary of Results for Subquestions One and Two

Subquestion One addressed the issue of commonalities in the lives and worldview of the eight artists interviewed, particularly with respect to their dual expertise in ornithology and the visual arts. Subquestion Two enquired if the artists’ stories offered support for the notion of the naturalist intelligence proposed by Howard Gardner (Gardner, 1999) The major common themes emerging from the interviews were the steady development of an innate drive toward practice as a professional bird artist; the view and practice of the work as art and/or science and how the artist perceived his or her identity as ornithologist or artist; the importance of expert perception of the organisms illustrated; the influential place of role-models and mentors to reinforce values and visions at certain stages of the artists’ development, and the importance of a community of others to support the artist’s distinctive worldview and to offer support for a specialized and isolated profession.

Two distinct patterns of career development were observed within the sample. The general direction of their lives became apparent to four of the artists - Dan Lane, Larry McQueen, John O’Neill, and Bill Strausberger - in their very early years. Their ‘career decisions’ were made by the ages of ten to twelve, and there was no deviation from the path toward bird art. The self-knowledge of who they were and what they were to be “struck like an annunciation’ (Hillman, 1996, p.3) and became apparent to them during otherwise insignificant incidents of childhood that are still clearly recalled.

In others – Eustace Barnes, Jim Coe, Doug Pratt, and Sophie Webb – there was no clear articulation of the calling toward bird art, until the middle to late twenties, when each of these

individuals actually arrived at their professional practice. The realization – such as it was – took the form of “I am a professional bird artist” as an adult, rather than the declaration, “I am going to be a bird artist” in childhood. In all cases, however, the calling to become a bird artist was initially driven by love of birds and/or other phenomena within the natural world, suggesting that the innate calling or ‘acorn’, might actually be a manifestation of Gardner’s naturalist intelligence (Gardner, 1999)

The timing of the articulation of the calling toward bird art seemed to make little difference to either the outcome or the process of preparation for the profession. All participants seem to have been diligently preparing themselves for their life-work or ‘growing down’ into their calling throughout their lives, practicing and developing relevant skills in biology and art. This skill development occurred via several pathways; conscious choices of curricula in higher education, leisure-time activities such as reading and self-study, and finding a network of skilled others with whom to pursue and expand their interests. A generalized level of family support for their activities was present throughout the sample, but in no case were specific role models present.

Two other aspects of the general life course of these artists are striking. One is a generalized drive toward autonomy, fully and consciously articulated in Barnes, Coe, McQueen, and O’Neill, all of whom made a deliberate decision to leave the security of institutions and formal employment for the independence to observe birds and paint as they chose. Three of the remaining four artists have also embraced this autonomous lifestyle. Lane, Pratt, and Webb did not explicitly report a time when they consciously made this decision, but all indicated that they had no interest in institutional employment, but preferred to continue to live and work as independent naturalists and artists. Bill Strausberger is a special case, having recently finished

his doctoral work in ornithology at the time of interview and moved into a position as a researcher almost as an automatic next step. His desires for the future are all framed in terms of independent research, writing, and painting projects, however, and it seems unlikely that he will remain ‘institutionalized’ as his career progresses.

Larry McQueen posited one final common aspect of the bird artists’ careers that is supported by the contents of the interviews. McQueen believes that the eventual direction of an ornithological artist’s specific career is rooted in an affinity for a particular environment, and that the group of birds of specific interest is a reflection of that environment. In his own case, he says, “There are certain environments that are very exciting to me – grassland prairie and forests – and the I like the birds of those environments because they are evocative of those places” this theory is supported by the evidence from the remainder of the sample.

Dan Lane, Eustace Barnes, and O’Neill have a deep love for the tropical rainforest, Pratt’s love is for the south Pacific Islands, Webb is drawn to the coastal environment, Coe prefers the woodlands and fields of the Northeastern United States, and Strausberger is attached to the birds of the mid-western prairie ecosystem. A number of the artists were quite explicit about this; Lane realized in his very early teens “I know I am going to be working in South America...I started taking Spanish and studying any tape or book I could get my hands on. Pratt was drawn to Hawaiian music and culture in elementary school; Webb grew up on Cape Cod “always loved the ocean”, prefers research and illustration to do with seabirds, and has written two children’s books about this group.

A process of maturation was implied with respect to the bird artists’ self concept with respect to the labels ‘artist’ and ‘scientist’. The young bird illustrator has the worldview of a scientist and sees himself/herself as such, and the approach to birds is one of categorizing and

compartmentalizing based on prior knowledge. With maturation of the individual as an artist, his visual experience widens and deepens, and there occurs a subtle perceptual shift from analysis of the form of an organism, a capture of morphological characteristics, to an appreciation of the bird's gestalt, or mature personality. This feeling for the gestalt or 'jizz' grows from a depth of knowledge beyond the morphological aspects of the bird, and the artist is more concerned with character, personality and habits. Following attainment of this deeper visual approach to the bird (akin to the Deweyan notion of aesthetic seeing (Dewey, 1934/1984), the artist begins to struggle with the nature of expression of his more mature perceptions, and at this point, he or she begins to think of himself/herself as an artist.

This process of maturation of perception and the resulting shift toward the artist identity, appears to be somewhat correlated with age or the length of career, however. Within this sample, John O'Neill, Larry McQueen, Jim Coe, and Doug Pratt explicitly declare themselves as 'artists', although O'Neill and Pratt are respected academic ornithologists, and Pratt continues to emphasize technical illustration in his own practice. Eustace Barnes tends to resist the label of artist, possibly due to the defenses he accumulated growing up in an artistic family, although he is a successful painter of narratives, and has an appreciation of that genre as a tool to introduce the non-specialist to the ecology of birds. Sophie Webb practices both forms of bird art, but has not aligned herself with either field: "I am a bird artist and a biologist; "There are periods of time in my life when I am mostly doing biology, and periods of time when I am mostly doing art." One of the younger artists in the sample, Dan Lane remains very much attached to his self-concept as a tropical ornithologist at this point and currently plans to remain involved in technical aspects of illustration.

A certain developmental process appears to be operating with this group of ornithological illustrators. Much as the interest in the organism has driven their interest in visual representation, they appear to first need to become firmly anchored and confident in an identity as ornithologist or biologist before the shift to the interest in expression and a self-concept as artist begins to emerge. The comments of Bill Strausberger, a relative newcomer to the field of ornithological illustration, illustrate this process in action. Strausberger is still very much a research ornithologist, but shows inclinations toward adopting the artist identity in the future; “Personally, I am very visual, I would describe myself as artistic. But it isn’t simple, because my biggest strength as an artist is my skill at observation, and that has been developed by analyzing what I see and noticing subtle gestures, different movements and behaviors. I do think that a real deep understanding of such things is more artistic than analytical.”

The opinions of these illustrators with respect to the question of whether there is a schism or dichotomy between technical illustration of birds and ‘art’ appears to be independent of their self-concept as ‘artist’ or ‘scientist.’ The comments of Coe, Lane, Webb and Pratt indicate that they believe that the two genres of bird art should be labeled separately as ‘technical illustration’ or ‘art painting.’ Barnes, McQueen, O’Neill, and Strausberger do not recognize a dichotomy. For example, Barnes claims that illustration work involves much of the creativity that is characteristic of narrative painting: “The artistry lies in making the right choices to convey the sense of the bird, you show something of what the bird is like physically, where and how it lives and behaves, picking the right light conditions, all combined in to a scene you have never actually seen in the field because illustration is so much more than photographic realism...its like telling a story...putting it altogether and making it aesthetically pleasing. There is definitely a

strong creative aspect to that.” O’Neill is also most emphatic on this point: “Good illustration cannot be separated from art.”

Whatever their self-concept, and belief regarding the place of illustration in art, all artists described approach to the two genres as different in terms of their work habits. Narrative painting was described as being approached as something as an enjoyable adventure, and being relatively rapid in execution, where technical illustration is an arduous linear process, extremely time-consuming, and requiring an intense focus upon a particular pre-planned outcome.

The most frequently referred to common theme within the interviews was the importance of expert perception to accurate and useful bird illustration, an aspect of the results that speaks directly to the issue of the naturalist intelligence. The depth of perception referred to combines highly tuned observations skills interacting with an expert knowledge base; an interaction that results in an enhanced understanding of what is seen. Each artist also emphasized the years of field experience necessary to build this understanding, illustrated by Webb’s comment: “You do not necessarily see what the bird is like at first...you have to spend enough time in the field to get the overall character”, a statement that was duplicated – in spirit if not verbatim – many times through each interview.

The remaining two themes discerned from the interviews – the presence of heroes, role models and mentors, and the importance of a community of practice - also have implications for the development and continued nurturance of the naturalist intelligence. The naturalist intelligence is not generally supported either in the wider society of the present day, or within the framework of formal education, although most participants did speak with gratitude of encouragement and assistance received from one particular key individual encountered during their grade school or college years. Although given a generalized degree of familial support, it

appears that the budding naturalists in this sample actively sought out materials, individuals, and institutions who provided support for their values and visions and offered active assistance in the maturation of their particular intelligence, and that they did this independently during their childhood and early teens. This building of a network of like-minded others continues when the individual naturalist's expertise is fully developed and recognized in term of professional success, and was manifested here by the value the participants placed upon their relationships with colleagues within their 'invisible college' of bird artists.



## CHAPTER 5: RESEARCH FINDINGS - ECOLOGICAL INFORMATION PRESENTED BY ORNITHOLOGICAL ARTWORK

The second section of this study asked two related questions:

1. Are the products of ornithological artists consistent with Edward Tufte's (1983; 1990; 1997) principles of graphical design, with respect to the transmission of qualitative, quantitative, and relational informational, and the stimulation of reasoning processes in the viewer?
2. How might ornithological imagery be used effectively in the high school and college classroom?

The analysis of the ecological information presented by ornithological art is divided into three parts. First (Section I), a sample of 40 narrative ornithological paintings was analyzed for the adherence of these works to Edward Tufte's (1983; 1990; 1997) criteria for successful scientific graphics, and mined for the variety of ecological and ornithological information made explicit – or implied by – these artworks. This was then repeated for a second sample of 40 plates from four popular and respected field guides to North American birds (Section II). In Section III, the educational potential of both paintings and field guide plates was considered in relation to the ecological topics described by the American Association of Science's *Benchmarks for Scientific Literacy* (1993), contained within the environmental science coverage in the *National Science Education Standards* (NRC, 1996), and the most important concepts in ecology ranked by the British Ecological Society Cherrett (1989).

### Section One: Narrative Ornithological Paintings As Scientific Graphics

#### Selection and Analysis of the Sample

The selection of images was severely constrained by the criterion that the image should be available online, and the desire that the painting should wherever possible include some

ecological component in addition to the ornithological subject matter. However, a sample of 40 images representing birds from North and South America, the Hawaiian archipelago, subarctic and Northern Europe, Africa, Australia, and New Guinea was eventually obtained. These works were produced by artists from the 17<sup>th</sup> century (e.g., Thomas Bewick's *The Rook* and *Great Auk*) through the early 21<sup>st</sup> century (e.g., Robert Bateman's *The Return – Bald Eagle*) and included five of the eight contemporary bird painters interviewed for the earlier part of this study. The complete sample is listed in Table 5.1, along with a reference number (1-40) that is utilized throughout this chapter.

Table 5.1. Sample of narrative ornithological paintings chosen for analysis with respect to their adherence to Edward Tufte's (1983; 1990; 1997) criteria for excellence in scientific graphics.

Ref. #	Artist	Title of Painting	Source
1.	John James Audubon 1785-1851 French/ American	Black-throated Guillemot, Nobbed-billed Auk, Curled- Crested Auk and Horned-billed Guillemot	<a href="http://www.nga.gov/cgi-bin/pimage?32559+0+0">http://www.nga.gov/cgi-bin/pimage?32559+0+0</a>
2.	John James Audubon	Ivory-billed Woodpecker	<a href="http://wampum.wabanaki.net/archives/ivory1.gif">http://wampum.wabanaki.net/archives/ivory1.gif</a>
3.	Robert Bateman b. 1930 Canadian	Three Ostriches on an Egg	<a href="http://www.robertbateman.ca/paintings/OstrichonEgg.htm">http://www.robertbateman.ca/paintings/OstrichonEgg.htm</a>
4.	Robert Bateman	The Return – Bald Eagle	<a href="http://www.robertbateman.ca/paintings/TheReturnBaldEagle.htm">http://www.robertbateman.ca/paintings/TheReturnBaldEagle.htm</a>
5.	Thomas Bewick 1753-1828 English	The Rook	<a href="http://liesl.sharecom.ca/bewick/landbirds/frlandbirds1797.html">http://liesl.sharecom.ca/bewick/landbirds/frlandbirds1797.html</a>
6.	Thomas Bewick	Great Auk	<a href="http://liesl.sharecom.ca/bewick/waterbirds/frwb1805.html">http://liesl.sharecom.ca/bewick/waterbirds/frwb1805.html</a>
7.	Mark Catesby 1683-1749 English/ American	Passenger Pigeon	<a href="http://www.loc.gov/exhibits/british/images/27avc.jpg">http://www.loc.gov/exhibits/british/images/27avc.jpg</a>
8.	Mark Catesby	Heron, eft, chigoe, cockroach... (Aka Great Blue Heron with Salamander)	<a href="http://rmc.library.cornell.edu/ornithology/guide/hillguide09.htm">http://rmc.library.cornell.edu/ornithology/guide/hillguide09.htm</a>

Ref. #	Artist	Title of Painting	Source
9.	James Coe b. 1957 American	Western Rock Shorebirds	<a href="http://birds.cornell.edu/onlineguide/coe_gallery.html">http://birds.cornell.edu/onlineguide/coe_gallery.html</a>
10	James Coe	Black-bellied Plovers	<a href="http://birds.cornell.edu/onlineguide/images/coe_black-bellied_plovers.jpg">http://birds.cornell.edu/onlineguide/images/coe_black-bellied_plovers.jpg</a>
11	Don Eckelberry 1921-2001 American	White-eared Puffbird	<a href="http://elibrary.unm.edu/sora/Auk/v078n01/p0001-p0002.pdf">http://elibrary.unm.edu/sora/Auk/v078n01/p0001-p0002.pdf</a>
12	Don Eckelberry	Yellow-crowned Night Heron	<a href="http://www.acnatsci.org/library/eckelberry/about.html">http://www.acnatsci.org/library/eckelberry/about.html</a>
13	Louis Agassiz Fuertes 1824-1927 American	Rails	<a href="http://www.nysm.nysed.gov/virtual/collections/fuertes/fuertes-main-noframes.html">http://www.nysm.nysed.gov/virtual/collections/fuertes/fuertes-main-noframes.html</a>
14	Louis Agassiz Fuertes	Appearance of Diurnal Birds of Prey in Flight	<a href="http://www.nysm.nysed.gov/virtual/collections/fuertes/fuertes-main-noframes.html">http://www.nysm.nysed.gov/virtual/collections/fuertes/fuertes-main-noframes.html</a>
15	John Gould 1804-1881 English	Quetzal	<a href="http://rmc.library.cornell.edu/ornithology/exhibit/exhibit4a.htm">http://rmc.library.cornell.edu/ornithology/exhibit/exhibit4a.htm</a>
16	John Gould	Spotted Bower Bird	<a href="http://spencer.lib.ku.edu/exhibits/gould/collections/bower.htm">http://spencer.lib.ku.edu/exhibits/gould/collections/bower.htm</a>
17	Lars Jonsson b. 1952 Swedish	Coastal Meadow – Oystercatchers	<a href="http://www.wildlifeartgallery.co.uk/paintings/lars_jonsson/lj_oyster.html">http://www.wildlifeartgallery.co.uk/paintings/lars_jonsson/lj_oyster.html</a>
18	Lars Jonsson	Atra (Desire) Shows group of Eider Ducks in open water habitat	<a href="http://www.worldtwitch.com/princeton_page_2.htm">http://www.worldtwitch.com/princeton_page_2.htm</a>
19	John Gerard Keulemans 1842-1912 Dutch	Pennula sandwichensis Hawaiian Spotted Rail	<a href="http://www.sil.si.edu/digitalcollections/nhrarebooks/rothschild/plates/plates_large/SIL6-3-155a.jpg">http://www.sil.si.edu/digitalcollections/nhrarebooks/rothschild/plates/plates_large/SIL6-3-155a.jpg</a>
20	John Gerard Keulemans	Pseudonestor xanthophrys, Rothschild Maui Parrotbill (honeycreeper)	<a href="http://www.sil.si.edu/digitalcollections/nhrarebooks/rothschild/plates/plates_large/SIL6-3-137a.jpg">http://www.sil.si.edu/digitalcollections/nhrarebooks/rothschild/plates/plates_large/SIL6-3-137a.jpg</a>
21	Dan Lane b.1973 American	Boat-billed Heron	<a href="http://birdingonthe.net/imgs/lane/Boat-billed_Heron.jpg">http://birdingonthe.net/imgs/lane/Boat-billed_Heron.jpg</a>
22	Dan Lane	Scarlet-banded Barbets	<a href="http://www.montereybay.com/creagrus/best_birds31-40.html">http://www.montereybay.com/creagrus/best_birds31-40.html</a>

<b>Ref. #</b>	<b>Artist</b>	<b>Title of Painting</b>	<b>Source</b>
<b>23</b>	Bruno Liljefors 1860-1939 Swedish	Sea Eagle Chasing Eider Duck Note: White-tailed eagle	<a href="http://www.artrenewal.org/asp/database/image.asp?id=11409">http://www.artrenewal.org/asp/database/image.asp?id=11409</a>
<b>24</b>	Bruno Liljefors	Bean-geese at Sunset	<a href="http://www.aida.net/wild7.htm">http://www.aida.net/wild7.htm</a>
<b>25</b>	Donald L. Malick 1929-1986 American	High Prairie	<a href="http://www.usaref.org/Donald%20L.%20Malick.htm">http://www.usaref.org/Donald%20L.%20Malick.htm</a>
<b>26</b>	Donald L. Malick	Martial Eagle on Ground Hornbill	<a href="http://www.usaref.org/Donald%20L.%20Malick.htm">http://www.usaref.org/Donald%20L.%20Malick.htm</a>
<b>27</b>	Francois Nicholas Martinet b. 1731 French	House Sparrows	<a href="http://www.sil.si.edu/DigitalCollections/NHRareBooks/Martinet/SIL13-1-105.htm">http://www.sil.si.edu/DigitalCollections/NHRareBooks/Martinet/SIL13-1-105.htm</a>
<b>28</b>	Francois Nicholas Martinet	Le Grand Martinet. Le Petit Martinet (Common Swift, Apus apus; Common House Martin, Delichon urbica).	<a href="http://www.sil.si.edu/DigitalCollections/NHRareBooks/Martinet/SIL13-1-124.htm">http://www.sil.si.edu/DigitalCollections/NHRareBooks/Martinet/SIL13-1-124.htm</a>
<b>29</b>	Larry McQueen b. 1936 American	Pacific Madrone and Anna's Hummingbird	<a href="http://shop.birdwatchersdigest.com/product.aspx?c=hummingbirds_cover_art_bwd(base)&amp;p=112341(base)">http://shop.birdwatchersdigest.com/product.aspx?c=hummingbirds_cover_art_bwd(base)&amp;p=112341(base)</a>
<b>30</b>	Larry McQueen	Forest Owlet	<a href="http://www.orientalbirdclub.org/./forowlet.html">www.orientalbirdclub.org/./forowlet.html</a>
<b>31</b>	John P. O'Neill b. 1942 American	Galapagos Finches	<a href="http://www.metalorchids.com/artists-detail-works-detail.php?currentid=3&amp;workid=364&amp;artistid=28">http://www.metalorchids.com/artists-detail-works-detail.php?currentid=3&amp;workid=364&amp;artistid=28</a>
<b>32</b>	John P. O'Neill	Black-throated Blue Warbler	<a href="http://www.metalorchids.com/artists-detail-works-detail.php?currentid=1&amp;workid=367&amp;artistid=28">http://www.metalorchids.com/artists-detail-works-detail.php?currentid=1&amp;workid=367&amp;artistid=28</a>
<b>33</b>	Douglas H. Pratt b. 1944 American	Brown Creeper	<a href="http://birdingonthe.net/imgs/pratt/thumbnails.html">http://birdingonthe.net/imgs/pratt/thumbnails.html</a>
<b>34</b>	Douglas H. Pratt	Drepanidinae Series: Apananes and Akepas	<a href="http://www.metalorchids.com/artists-detail-works-detail.php?currentid=42&amp;workid=501&amp;artistid=18">http://www.metalorchids.com/artists-detail-works-detail.php?currentid=42&amp;workid=501&amp;artistid=18</a>
<b>35</b>	J. Lebrecht Reinhold 1744-1807 German	Egyptian Vulture	<a href="http://www.brenthurst.org.za/thirdbs.htm">http://www.brenthurst.org.za/thirdbs.htm</a>

36	J. Lebrecht Reinhold	Fiscal Shrike	<a href="http://www.brenthurst.org.za/thirdbs.htm">http://www.brenthurst.org.za/thirdbs.htm</a>
37	Archibald Thorburn 1860-1935 Scottish	Gyr Falcon Or Greenland Falcon	<a href="http://www.artrenewal.org/asp/database/art.asp?aid=566&amp;page=1">http://www.artrenewal.org/asp/database/art.asp?aid=566&amp;page=1</a>
38	Archibald Thorburn	Blue Tits on a Teasel	<a href="http://www.artrenewal.org/asp/database/art.asp?aid=566&amp;page=1">http://www.artrenewal.org/asp/database/art.asp?aid=566&amp;page=1</a>
39	Richard Weatherley b. 1947 Australian	Carpentarian Grasswren Amytornis dorotheae	<a href="http://www.montereybay.com/creagrus/best_birds41-50.html">http://www.montereybay.com/creagrus/best_birds41-50.html</a>
40	Richard Weatherley	Campbell's Fairywren	<a href="http://www.montereybay.com/creagrus/fairywrens.html">http://www.montereybay.com/creagrus/fairywrens.html</a>

Each painting was analyzed using the rubric in Appendix B, which sought to assess how and where the painting conformed to Tufte's criteria for scientific graphics. Validation of the appropriateness of the paintings selected for the sample, and also of representative sections of the rubric was conducted by three independent reviewers with expertise in the field of ornithological illustration (listed in Appendix F). This expert panel was asked to check off an overall "yes or no" for each painting in the posited sample and the accompanying analysis of the rubric to determine their degree of agreement with both the selection and the author's approach to analysis. An agreement analysis between the author's selection of the paintings and the analysis of the accompanying rubric yielded across the selection of paintings a Fleiss Kappa value of .91 ( $\alpha = 0.05$ ) indicating a high degree of agreement between the three reviewers and the author.

The results of the analysis of this sample of paintings are reported below by grouping Tufte's criteria under the following sub-headings:

- i) Structure of the painting: analysis of the presence of a micro-macro approach to the scene, use of the PGP (particular-general-particular) strategy, the deliberate use of visual hierarchies within the painting, and the emergence of an ecological theme or

‘story’ as the eye traveled the painting. Potential compromises between ecological realism and ornithological technicalities.

- ii) Integrity of the painting with respect to qualitative and quantitative aspects of the subject matter portrayed.
- iii) Provision of multiple dimensions of information: if and how the sample of paintings incorporated the dimension of time, and the extent to which the variables of form, size, behavior, habitat, and distribution of the birds were included.
- iv) Visual comparisons that were enforced or suggested within the paintings.
- v) Inclusion of relational phenomena that enhanced the ecological content of the paintings, and the lines of ecological interest and reasoning that might potentially be stimulated by these.

#### Structure of Ornithological Narrative Paintings with Respect to Tufte’s Criteria for Scientific Graphics

Several structural design strategies recommended by Tufte (1990) for enhanced density, complexity, and dimensionality in scientific graphics are relevant to ornithological and other natural history painting. These include micro-macro approaches to a scene, the closely related but more sequenced PGP approach, and the layering and separating information via the presentation of deliberate visual hierarchies.

Examination of this sample of ornithological narrative paintings determined that 35 (87.5%) of the 40 works utilized a micro-macro approach, in which detailed smaller structures culminate in larger cohesive structures (Table 5.2). The micro-macro structure appears to be

inherent to this genre, for in those works where an appropriate background is provided, a situation naturally arises in which details of individual birds provide a micro-structure, while the habitat and background elements provide an extended (macro) structure as the ecological setting of those individuals or species is described. Those paintings that could not be interpreted from a micro-macro aspect were either predominantly portraits with only minimal habitat elements depicted, or field-plate type paintings in which multiple portraits of related species suggested more a “micro-micro” orientation ( Table 5.3). The strengths of this latter type of painting were later found to lie in visual comparisons, which do not combine well with the informational hierarchy required for the micro-macro display.

**Table 5.2. Micro-macro approaches to subject matter discerned within 35 of the sample of 40 narrative ornithological paintings.**

<b>Painting</b>	<b>Micro/Macro Structure(s) Discerned</b>
Audubon: Black-throated Guillemot, Nodded-billed Auk, Curled- Crested Auk and Horned-billed Guillemot	Four species of one family shown as distinct individual portraits (micro-structures) against a generalized background depicting common habitat (macro-structure)
Audubon: Ivory-billed Woodpecker	Four individuals of one species engaged in different behaviors and shown in different views with different postures (variety of micro-structures) in typical habitat (macro-structure)
Bateman: The Return – Bald Eagle	Two individuals of one species engaged in different behaviors and shown in different views (various micro-structures) with different postures in typical habitat (macro-structure).
Bewick: The Rook	Detailed portrait of single individual against background that imparts ecological information with respect to that species.
Bewick: Great Auk	Detailed portrait of single individual against background that imparts ecological information with respect to that species
Catesby: Passenger Pigeon	Detailed portrait of single individual with background elements providing some ecological information with respect to that species.
Catesby: Heron, eft, chigoe, cockroach...	Detailed portrait of head of individual bird with background elements providing information with respect to feeding ecology of that species
Coe: Black-bellied Plovers	Six individuals of one species shown as distinct individual portraits (all micro-structures) against a generalized background depicting typical common habitat.
Coe: Western Rock Shorebirds	Six species shown as distinct individual portraits against a generalized background depicting typical common habitat.
Eckelberry: Yellow-crowned Night Heron	Two individuals of one species engaged in different behaviors and shown in different views with different postures in typical habitat.
Fuertes: Rails	Five individuals of three species engaged in different behaviors and shown in different views with different postures(various micro-structures) in typical habitat.
Fuertes: Diurnal Birds of Prey in Flight	Plate (portraits of multiple species) with common elements of habitat depicted
Gould: Quetzal	Two individuals of one species shown in typical habitat
Gould: Spotted Bowerbird	Two individuals of one species shown in typical habitat
Jonsson: Coastal Meadow Oystercatchers	Two individuals of one species engaged in different behaviors and shown in different views with different postures in typical habitat.
Jonsson: Atrá (Desire)	Five individuals of one species engaged in different behaviors and shown in different views with different postures in typical habitat



<b>Painting</b>	<b>Micro/Macro Structure(s) Discerned</b>
Keulemans: Pennula sandwichensis (Hawaiian Spotted Rail)	Two individuals of one species shown in typical habitat
Keulemans: Pseudonestor xanthophrys (Maui Parrotbill)	Two individuals of one species in different views shown against tropical vegetation typical of their habitat
Lane: Scarlet-banded Barbets	Two individuals of one species in different views shown against tropical vegetation typical of their habitat.
Liljefors: Sea Eagle Chasing Eider Duck	Two individuals of two species engaged in different behaviors shown in typical habitat
Liljefors: Bean Geese at Sunset	Multiple individuals of one species engaged in different behaviors and shown in different postures in typical habitat.
Malick: High Prairie	Two individuals of two species engaged in different behaviors shown in typical habitat
Malick: Martial Eagle on Ground Hornbill	Two individuals of two species engaged in different behaviors shown in typical habitat
Martinet: House Sparrows	Two individuals of one species presented as individual detailed portraits shown against typical habitat
Martinet: Le Grande Martinet; Le Petit Martinet	Two individuals of two species engaged in different behaviors shown in typical nesting habitat
McQueen: Anna's Hummingbird and Pacific Madrone	Detailed portrait of one individual depicted against important characteristic elements of habitat
O'Neill: Black-throated Blue Warbler	Portraits of two adults of one species depicted against characteristic habitat and including nest and chicks.
Pratt: Brown Creeper	Detailed portrait of one individual depicted against important characteristic elements of habitat.
Pratt: Apapanes and Akepas	Portraits of two individuals of two related species depicted against important characteristic elements of habitat
Reinhold: Egyptian Vulture	Detailed portrait of individual bird with background elements providing information with respect to feeding ecology of that species
Reinhold: Fiscal Shrike	Detailed portrait of individual bird with background elements providing information with respect to feeding ecology of that species.
Thorburn: Gyr Falcon	Detailed portrait of individual bird shown in typical habitat
Thorburn: Blue Tits on a Teasel	Portrait of two individuals of one species engaged in different behaviors shown in typical habitat
Weatherly: Carpenterian Grasswren	Detailed portrait of one individual depicted against important characteristic elements of habitat
Weatherly: Campbell's Fairywren	Portrait of two individuals of one species shown in typical habitat

**Table 5-3. Works in the sample of 40 narrative ornithological paintings where a micro-macro approach to subject matter was not evident**

Painting	Notes
Bateman: <i>Three Ostriches on an Egg</i>	Portrait with no/minimal habitat depicted
Eckelberry: <i>White-eared Puffbird</i>	Portrait with no/minimal habitat depicted
Lane: <i>Boat-billed Heron</i>	Portrait with no/minimal habitat depicted
McQueen: <i>Forest Owlet</i>	Portrait with no/minimal habitat depicted
O'Neill: <i>Galapagos Finches</i>	Plate (portraits of multiple species) with no/minimal habitat depicted

A design problem within narrative ornithological illustration is that of revealing ornithological aspects of the bird subjects in as much detail as possible, while giving a clear picture of the setting within which the species lives and functions. In other words, the ideal is to give maximum information about the actual subject, while clarifying that information within a wider setting. Tufte's recommended solution for such a situation is the PGP (particular-general-particular) approach – a type of sequenced micro/macro solution - where the illustration highlights a particular relevant detail or data point, then describes the general architecture of the data or subject, finally reinforcing the general with a second particular (Tufte, 1997, pp 68-9). Thus two particulars highlight and help to explain the general data arrangement. PGP is ideal for quantitative data displays, but its potential for use in natural history illustration lies in the arrangement of plates depicting different but related species. Here the two (or more) species would appear as the 'particulars.'

Table 5.4 describes how 39 (97.5%) of the 40 paintings in the sample successfully employed a PGP approach. Bateman's *Three Ostriches on an Egg* proved to be the only painting where this sequential approach to the delivery of information could not be discerned: the three-

dimensional medium of the egg upon which the individual birds were shown presented too much difficulty for the eye to follow a sequenced delivery of information.

Each of the paintings identified as having micro-macro architecture was also found to possess a PGP sequence. Some recognizable patterns emerged. In those paintings that are essentially individual bird portraits (e.g., Eckelberry's *White-eared Puffbird*, Reinhold's *Egyptian Vulture*, and O'Neill's *Galapagos Finches*), the viewer is led through the PGP sequence by first focusing attention upon the head and bill, often achieved by use of a strong white highlight, such as in the bird's eye. After examination of the head region, the eye wanders over details of the habitat, and is led downward by the background toward the feet of the bird (the second particular). The examination of particulars of the bird is then re-initiated, first by a study of the feet, and then to an examination of the overall form and posture as the eye again travels upward. Paintings showing multiple individuals of one species (e.g., Coe's *Black-bellied Plovers* and Keuleman's *Pennula sandwichensis*) frequently invited the viewer to identify the species as a first particular, examine the habitat against which the birds were shown, then return to a comparison of the different views or behaviors of the individuals.

The PGP sequence was very much in evidence in mixed species paintings, as the eye first identified the gross differences between species, then took in the common environment, and finally returned to a perusal of details of the individual species portraits (e.g., Audubon's *Black-throated Guillemot*, *Nobbed-billed Auk*, *Curled-Crested Auk* and *Horned-billed Guillemot*, Coe's *Western Rock Shorebirds*, and Martinet's *Le Grande Martinet*; *Le Petit Martinet*.) Other PGP sequences were identified that utilized features of the environment as particulars (e.g., Catesby's *Passenger Pigeon*, Gould's *Quetzal*, McQueen's *Anna's Hummingbird* and *Pacific Madrone*, and Pratt's *Brown Creeper*). These last two works are oddities in that the bird is introduced to the

eye only after details of the habitat have been explored. Where the focus of the painting was of an interaction between the birds, such as the predation events depicted in Liljefors' *Sea Eagle Chasing Eider Duck* and Malick's *Martial Eagle on Ground Hornbill*, the interaction itself typically formed the general architecture of the scene, with each of the bird 'participants' representing particulars. Table 5.4 describes the PGP sequence discerned in each of the paintings in detail.

Table 5.4. PGP (Particular-General-Particular) sequences discerned within the sample of narrative ornithological paintings.

Painting	PGP sequence
Audubon: Black-throated Guillemot, Noddy-billed Auk, Curled-Crested Auk and Horned-billed Guillemot	Eye drawn first to birds, then to environment characteristic of all four related species, and finally to details (crest, horn, etc.) that distinguish the four superficially similar species of Alcid.
Audubon: Ivory-billed Woodpecker	Eye drawn first to characteristics of the Ivory-billed Woodpecker, then takes in the habitat details, and finally returns to identify gender differences between the individuals illustrated.
Bateman: The Return – Bald Eagle	First particular is returning bird; eye then takes in nesting scene, then drawn to reaction of second bird to returning mate. Thus PGP is male bird – background – female bird.
Bewick: The Rook	First particular – foreground portrait of rook. General architecture is that of environment. Eye finally drawn to behavior of other rooks in background.
Bewick: Great Auk	First particular is foreground portrait of Great Auk. General architecture is that of environment. Eye then returns to particular features of the auk, such as the ridged mandibles.
Catesby: Passenger Pigeon	First particular is that of acorn. General architecture is that of the portrait of the Passenger Pigeon. Eye then takes in the oak leaves in background.
Catesby: Heron, eft, chigoe, cockroach...	First particular is the portrait of Great Blue Heron. Eye then wanders through the visual list of other organisms, recognizing these as prey items, then returns to examine and classify the prey organisms individually.
Coe: Black-bellied Plovers	Eye drawn to grouped birds by areas of bright white, then takes in habitat, then details of individual birds in the group, leading in turn to visual comparison of plumages related to age, sex, and breeding condition.

Painting	PGP sequence
Coe: Western Rock Shorebirds	Two examples of the PGP strategy operate simultaneously here. The first draws the eye to the birds, takes in the habitat (portion of rocky shore upon which the birds stand or perch), then returns to detect comparisons between the individuals and species. Second, the eye is drawn to the habitat of the rocky shore, and then places this within the larger coastal environment illustrated, then returns to finer details of the habitat, such as the algae and barnacles.
Eckelberry: Yellow-crowned Night Heron	Eye first drawn to male heron by bright white areas on head, then to background architecture of mangrove swamp, then to particulars of female heron feeding.
Eckelberry: White-eared Puffbird	White areas around eye and highlighted pupil draw attention first to details of the head of the bird, and then to overall features of the body. Finally, a second area of less bright white on the belly and underparts draws attention to the feet and posture of the bird, again important to the 'jizz' or character.
Fuertes: Diurnal Birds of Prey in Flight	First particular is the flight silhouette of each species. Eye is then led to compare the remaining silhouettes that form the general architecture of the image in the absence of habitat details, then again for each species returns to the individual details of morphology. The eye is repeatedly drawn back and forth between comparing the flight silhouettes and individual morphological details of each species.
Fuertes: Rails	Eye alerted first by larger birds (Yellow Rail and Sora), then drawn to habitat common to all three species of the Rallidae, and finally takes in the details of the smaller Little Black Rail and the chicks.
Gould: Quetzal	Eye takes in nesting pair in foreground, then cloud forest environment and other quetzals shown as background, finally returning to details of nest and vegetation in foreground.
Gould: Spotted Bowerbird	Eye first alerted by the two birds, then drawn to background of bower, finally returning to a visual comparison of the two individuals that 'makes sense' of the background.
Jonsson: Coastal Meadow Oystercatchers	Eye takes in standing chick in center of painting, travels to coastal meadow environment depicted in background, and finally returns to hatching chick and details of nest in foreground.
Jonsson: Atrá (Desire)	Eye alerted first by large individual eider duck landing on water, takes in pelagic environment, then returns to examine other individual eiders in less active poses.

Painting	PGP sequence
Keulemans: <i>Pennula sandwichensis</i> (Hawaiian Spotted Rail)	Eye alerted first by two rails in center of painting, takes in background details of local habitat, then returns to comparison of male/female plumage differences.
Keulemans: <i>Pseudonestor xanthophrys</i>	Eye alerted first by canonical portrait of honeycreeper in center, takes in background details of local habitat, then returns to examine details of second honeycreeper shown in quasi-dorsal view as it feeds upon 'Ohi'a.
Lane: Boat-billed Heron	Eye alerted first by head and body of heron, takes in details of surrounding foliage, then returns to details of perch and feet.
Lane: Scarlet-banded Barbets	Eye alerted first by barbet shown in ventral view, takes in details of surrounding foliage then returns to barbet shown in canonical view.
Liljefors: Sea Eagle Chasing Eider Duck	Eye takes in predator (White-tailed eagle), then environment in which predatory event is taking place, then returns to prey item (Eider Duck)
Liljefors: Bean Geese at Sunset	Eye takes in birds standing in foreground, then marsh habitat, then takes in birds flying in to roosting area
Malick: High Prairie	Eye takes in predator (falcon), then prairie environment in which predatory event is taking place, then returns to prey item.
Malick: Martial Eagle on Ground Hornbill	Eye takes in details of feeding eagle, and then registers the nature of the interaction, finally alighting on details of the dead hornbill.
Martinet: House Sparrows	Eye drawn to female sparrow, then registers rooftop habitat and returns to portrait of male sparrow.
Martinet: Le Grande Martinet; Le Petit Martinet	Eye drawn first to portrait of Common Swift, then registers the local habitat shown and returns to portrait of House Martin.
McQueen: Anna's Hummingbird and Pacific Madrone	Eye drawn first to large inflorescences of Madrone, then foliage of this plant that provides general architecture of narrative, and finally alights on hovering hummingbird preparing to feed. Note that bird is introduced after the eye has explored details of the habitat.
McQueen: Forest Owlet	Eye drawn first to owlet shown in dorsal view, then registers background of foliage, finally alights on portrait of second owlet shown in ventral-canonical view.
O'Neill: Galapagos Finches	For each of the five portraits, eye is drawn first to the head and bill details, then to the overall form and posture of the bird, and finally to details of the feet.

Painting	PGP sequence
O'Neill: Black-throated Blue Warbler	Eye drawn first to parents, then to background with foliage and nest, and finally to nestlings.
Pratt: Brown Creeper	Eye drawn first to detail of fungus, then to tree trunk (local habitat) and finally to bird. Note that bird is introduced after the eye has explored details of the habitat.
Pratt: Apapanes and Akepas	Eye drawn first to portrait of Apapane, then registers details of the 'Ohi'a forest (habitat), and finally to portrait of Akepa
Reinhold: Egyptian Vulture	Eye drawn first to head and bill of vulture, then background, finally bone in foreground returns attention to feet of bird and its overall form and posture.
Reinhold: Fiscal Shrike	Eye drawn first to portrait of bird, then takes in background, is alerted by insect prey items, returning attention to bird
Thorburn: Gyr Falcon	Eye drawn first to head and bill of bird by fierce eye, then takes in environmental setting; finally tiny feather from previously ingested prey item near feet of bird draws attention to talons and then overall form.
Thorburn: Blue Tits on a Teasel	Eye first registers form of brightly colored tits, then takes in habitat, returns to details of activity, particularly the tits use of their bills and feet as they feed.
Weatherly: Carpenterian Grasswren	Eye drawn first to head of bird by areas of bright white around eye and chin, then takes in habitat, returns to feet of bird from which overall form, posture, and 'jizz' of the little grasswren is noticed.
Weatherly: Campbell's Fairywren	Eye first alerted by bright white of striped head of fairywren at top left, which is assisted by placement of white fungus on tree. Eye then takes in the general habitat details – very complex in this case – and is led to consider the overall form and posture of the second bird shown in canonical view at bottom right.

Tufte (1990) holds that for structural strategies such as the micro/macro and PGP approaches to be exploited to the fullest by the viewer, a visual hierarchy achieved by variations in saturation of color, line weight, and texture, and assisted by compositional technique, is desirable. This visual hierarchy orders the sequence in which the eye and mind encountered the information structured by the painting or graphic.

The extent to which the artists of these 40 narrative paintings employed strategies of visual hierarchy was rated upon a Likert scale, with the rating based upon a collective agreement by the author and expert panel as to whether the relative importance of different elements of the paintings were clearly indicated by the artist's use of line weight, a hierarchy of color saturation, textural variations, or a combination of the above techniques. The particular techniques used in each painting were also identified.

All paintings were rated as either displaying an extensive use of visual hierarchical techniques, or as displaying a moderate use of such strategies. Detailed comments upon the actual strategies utilized are presented in Table 5.5 and Table 5.6. A rating of 'extensive use' of visual hierarchical strategies was earned by 34 of the 40 paintings (85% of the sample). Thirty of these paintings relied on compositional techniques to highlight the most important information, either placing the birds in the center of foreground of the painting, and also using an eye-catching detail to then direct the eye to important secondary elements. A common strategy was to use a bright spot of color (most frequently white) to draw the eye to the bird's head, then a slightly less bright spot to draw attention to the feet and any other important field marks. Sometimes a background element, such as the fungi in Pratt's *Brown Creeper* and Weatherly's *Campbell's Fairywren* was highlighted, and placed near an important avian feature in such a way as to direct the eye to this information. When backgrounds were so data-rich as to be potentially 'noisy,' more important elements were indicated by heavier use of lines, as in Malick's *High Prairie* and Liljefors' *Bean Geese at Sunset*.

Of those six works making only moderate use of layering and separation of data, three - Coe's *Western Rock Shorebirds*, Lane's *Boat-billed Heron*, and Pratt's *Apapanes and Akepas* - were intended as technical illustrations, where all aspects of the image may be presumed to be of



equal importance. Even these used some layering strategy to separate information on the actual birds, subtle variations in color saturation being the most frequent approach to this

Table 5.5. Narrative ornithological paintings rated as displaying extensive use of visual hierarchical techniques.

Painting	Strategies Employed to Achieve Visual Hierarchy	Notes
Audubon: Black-throated Guillemot, Noddy-billed Auk, Curled- Crested Auk and Horned-billed Guillemot	Compositional technique Subtle color variation	Birds shown in more saturated colors than background; eye moves from species to species without distraction by background elements.
Audubon: Ivory-billed Woodpecker	Compositional technique Textural variation	Posture of male draws attention to female feeding; variation of texture separates information in background.
Bateman: The Return – Bald Eagle	Compositional technique Subtle color variation Textural variation	Eye travels from left to right, taking in returning male, nest, and perching female. Details of each bird emphasized by variations of texture of feathers and color of plumage.
Bewick: The Rook	Compositional technique Variation of line weight	Bird portrait dominates, occupying center of painting; Bewick uses a hierarchy of line weight to order the importance of the many background elements.
Bewick: Great Auk	Compositional technique Variation of line weight	Bird portrait dominates, occupying center of painting; Bewick uses lighter and hierarchical line weights for the background elements.
Catesby: Passenger Pigeon	Compositional technique Subtle color variation Variation of line weight	Use of line weight interesting – lines and color of oak leaves heavier than bird, indicating importance of habitat to this species.
Coe: Black-bellied Plovers	Compositional technique Subtle color variation Variation of line weight	Birds occupy center of painting, eye travels right to left making comparisons. Color more saturated in birds than in background. Plumage details that distinguish non-breeding birds from similar species emphasized with heavier lines.
Eckelberry: White-eared Puffbird	Variation of line weight Subtle color variation Textural variation	Saturated colors on head draw attention to bill and bristles; line and texture used for plumage details.
Eckelberry: Yellow-crowned Night Heron	Compositional technique Variation of line weight	Composition draws eye to male then female bird; varied lines used to

		emphasize details of birds and crab: these are not employed in more impressionistic background.
Fuertes: Rails	Variation of line weight Subtle color variation Textural variation	Masterly use of subtle variations in line, color, and texture to differentiate cryptic species from complex background.
Fuertes: Diurnal Birds of Prey in Flight	Variation of line weight Subtle color variation Textural variation	Compositionally, each bird species given equal emphasis; each stands out from a background muted with respect to color saturation and using lighter lines to show details.
Gould: Quetzal	Compositional technique Subtle color variation Textural variation	Nesting pair in center of foreground; background elements hierarchical with respect to color saturation and separated by textural differences.
Gould: Spotted Bowerbird	Compositional technique Variation of line weight	Lightly sketched birds with respect to habitat elements; this separation actually draws attention to the interaction between the birds (the courtship ritual). Here, that which is suggested and half-hidden actively alerts the eye.
Jonsson: Coastal Meadow Oystercatchers	Compositional technique Subtle color variation Textural variation	Compositionally, eye is arrested by head-on portrait of standing chick, is led to eggs and emerging chick, then to lightly colored but detailed elements of complex background. Texture and saturation of color used to further separate avian elements from vegetation and background.
Jonsson: Atrá (Desire)	Compositional technique Subtle color variation Textural variation	Composition leads the eye through the individual bird portraits in a “V”. Birds separated from background by more saturated colors. Differences in plumage quality in each portrait achieved by textural variations.
Keulemans: Pennula sandwichensis (Hawaiian Spotted Rail)	Compositional technique Variation of line weight Subtle color variation Textural variation	Keulemans places birds in center of foreground, then varies all three strategies to display differences in plumage on each bird, between the two birds, and between avian and background elements.
Keulemans: Pseudonestor xanthophrys	Compositional technique Variation of line weight Subtle color variation Textural variation	Keulemans places birds squarely in center of painting, then varies all three strategies to display differences in plumage on each bird, between the two birds, and between

Lane: Scarlet-banded Barbets	Compositional technique Subtle color variation	avian and background elements.  Birds placed in foreground, then variation of saturation of color differentiates foreground from background.
Liljefors: Sea Eagle Chasing Eider Duck	Compositional technique Variation of line weight Subtle color variation Textural variation	Attention drawn to eagle by more saturated colors, and much attention to differentiation of details on bird by use of color, line and texture. Duck and background elements more impressionistic and less detailed.
Liljefors: Bean Geese at Sunset	Compositional technique Variation of line weight Subtle color variation Textural variation	Eye travels in a diagonal from roosting flock in foreground (primary element) to flying birds (secondary element) then wanders over background (tertiary element). The primary element is distinguished by great attention to detail using variations of color saturation, texture, and line.
Malick: High Prairie	Compositional technique Variation of line weight Subtle color variation Textural variation	Composition draws attention to interaction between species. Bird subjects painted in more saturated colors and given much more line detail than is habitat.
Malick: Martial Eagle on Ground Hornbill	Compositional technique Subtle color variation Textural variation	Strong composition, and birds differentiated from background by attention to the texture of plumages and use of strong colors.
Martinet: House Sparrows	Variation of line weight Subtle color variation Textural variation	Line weight is major strategy employed to draw attention to details of the birds; lines on architectural background are lighter and softer.
McQueen: Anna's Hummingbird and Pacific Madrone	Compositional technique Variation of line weight Subtle color variation	Unusual composition with active bird small relative to static vegetation. Importance of bird and inflorescence indicated by more saturated colors and more attention to line, while background of foliage is soft.
McQueen: Forest Owlet	Compositional technique Variation of line weight Subtle color variation Textural variation	Clever composition shows all aspects of bird using only two portraits; field marks on individuals highlighted by a combination of line, areas of saturated color, and textual variations, while background is impressionistic and soft.

O'Neill: Galapagos Finches	Compositional technique Variation of line weight	Composition ensures that each bird in plate given equal importance. Important field marks, particularly bills, given emphasis with heavier lines, forcing a visual comparison of this feature between the five species.
O'Neill: Black-throated Blue Warbler	Compositional technique Variation of line weight Subtle color variation	Composition places the birds in a "V", beginning with adult male, ending with adult females, and placing nest and chicks in center. Important field marks indicated with stronger lines and areas of saturated color. Background softer and impressionistic.
Pratt: Brown Creeper	Compositional technique Variation of line weight Textural variation	Position of fungal growth on tree draws attention to the bird; otherwise line and texture are utilized to draw attention to important details.
Reinhold: Egyptian Vulture	Compositional technique Subtle color variation	Straightforward composition. Saturated color on head and bill draws attention first to those areas, then area of bright white on thigh draws eye downward to notice details of feet and then areas of habitat.
Reinhold: Fiscal Shrike	Compositional technique Subtle color variation	Areas of brighter white guide eye through bird portrait; prey item at bottom right and foliage surrounding bird rendered in more muted colors with fewer lines.
Thorburn: Gyr Falcon	Compositional technique Variation of line weight Subtle color variation Textural variation	Bird in center of foreground rendered in saturated color with distinguishing details given emphasis with heavy lines; background colors in lighter wash and details rendered with lighter lines.
Thorburn: Blue Tits on a Teasel	Compositional technique Variation of line weight Subtle color variation Textural variation	Eye is drawn to birds by areas of bright, saturated color. Extensive and heavier lines used to indicate details on birds and teasel; background meadow rendered in broader strokes and less saturated hues.

Weatherly: Carpenterian Grasswren	Compositional technique Variation of line weight Subtle color variation Textural variation	Background rocks frame bird. The cryptic colors of the grasswren are rendered in less saturated hues than that of the habitat element, thus forcing attention to the bird. Habitat elements are less texturized and detailed, and have fewer details shown by heavy lines than does the bird. This cryptic species is emphasized more by varying line weight and texture than color.
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**Table 5.6. Narrative ornithological paintings rated as displaying moderate use of visual hierarchical techniques.**

Painting	Strategies Employed to Achieve Visual Hierarchy	Notes
Bateman: Three Ostriches on an Egg	Subtle color variation Textural variation	Areas of individual birds varied by color and texture; hierarchical aspect of painting as a whole difficult to determine given three-dimensional nature and curved surface of egg.
Catesby: Heron, eft, chigoe, cockroach.	Compositional technique	Heron placed centrally; relative importance of the various prey items to diet is not indicated.
Coe: Western Rock Shorebirds	Subtle color variation	Areas of bright white and saturated color used to emphasize details on individual birds, but painting as a whole not hierarchical; data-rich background is quite noisy.
Lane: Boat-billed Heron	Variation of line weight Subtle color variation	Areas of light and dark used to emphasize head of bird, and heavier lines draw attention to feet and perch, otherwise little hierarchical strategy.
Pratt: Apapanes and Akepas	Subtle color variation	Light areas and areas of saturated color used to draw attention to certain features of birds and plant; overall, little hierarchical strategy.
Weatherly: Campbell's Fairywren	Subtle color variation	Painting rich in bright and saturated colors, and extensive detail provided by line work throughout, tending to obscure hierarchy. Some elements of birds, fungi, and plants highlighted by areas of bright color.

The careful and deliberate visual structuring of a narrative painting, by use of micro-macro approaches, PGP designs, and elaborate visual hierarchies implies that the artist has a very particular tale to tell his or her viewer. With this in mind, the sample of narrative ornithological paintings were also examined for the emergence of a visual ‘story line’ about the bird subjects,

one which led the eye easily and naturally throughout the painting. This proved difficult to rate on a Likert scale, as called for by the original rubric, since the identification of ecological story lines was extremely subjective. However, the stories that seemed to emerge from the author's perspective, and also were validated by the expert panel, are listed in Table 5.7. These implicit stories potentially have educational relevance; a theme examined later in this chapter. At this stage, it is sufficient to state that at least one ecological story line emerged from each of the paintings. Even a simple canonical portrait, such as Eckelberry's *White-eared Puffbird* tells a tale of ecomorphology and adaptation, and invites speculation about that species' classification, habitat, and distribution. Some paintings depicting multiple species, and/or rich in behavioral interactions and habitat details contain within them the possibility of many biologically oriented stories. In such cases (e.g., Fuertes' *Diurnal Birds of Prey in Flight*; Pratt's *Apapanes and Akepas*; Weatherly's *Campbell's Fairywren*), the three or four most obvious 'plots' have been listed. The majority of these are straightforward ornithological topics and ecological issues, however, paintings depicting recently discovered birds, or rediscovery of birds previously believed to be extinct, also contain implicit stories of the nature of discovery in non-experimental branches of science (see Table 5.7; McQueen's *Forest Owlet* and Weatherly's *Campbell's Fairywren*).

**Table 5.7. Explicit Or Implied "Stories" Within The Sample Of 40 Narrative Ornithological Paintings.**

Painting	Biological/Ecological 'Story Line(s)' Detected
Audubon: Black-throated Guillemot, Nodded-billed Auk, Curled- Crested Auk and Horned-billed Guillemot	Adaptations of four species to the environment of the North Pacific coast; ecology and evolution of seabirds
Audubon: Ivory-billed Woodpecker	Life-cycle of trees; interdependence of birds and food plants; extinction; nature of science – continual revision of beliefs in the face of new evidence
Bateman: Three Ostriches on an Egg	Evolution of flightlessness and subsequent adaptations to this state implied

<b>Painting</b>	<b>Biological/Ecological ‘Story Line(s) ‘ Detected</b>
Bateman: The Return – Bald Eagle	Implications of food shortages to the population success of these birds
Bewick: The Rook	The success of this species in an agricultural environment; coevolution of human society and certain bird species
Bewick: Great Auk	Adaptation of this species to northern coastal habitat; ecology and evolution of seabirds; extinction
Catesby: Passenger Pigeon	Extinction; role of hardwood forests in the story of the extinction of the Passenger Pigeon.
Catesby: Heron, eft, chigoe, cockroach...	Feeding ecology of the Great Blue Heron; plasticity of diet in birds generally believed to be fish-eaters; community of organisms in freshwater habitats.
Coe: Western Rock Shorebirds	Ecology of the rocky shore; reproductive ecology (sexual display and mate choice implied by seasonal plumages).
Coe: Black-bellied Plovers	Ecology of the sandy beach habitat; reproductive ecology of the species (sexual display and mate choice implied by seasonal plumages).
Eckelberry: White-eared Puffbird	Ecomorphology and taxonomy of species. Visual description of (then) new species; dissemination of information about new discoveries to the scientific community.
Eckelberry: Yellow-crowned Night Heron	Ecology of mangrove swamp; ecomorphology and reproductive behavior (implied by paired adults) of species.
Fuertes: Diurnal Birds of Prey in Flight	Role of top predators in a marsh habitat and food webs within the marsh, also implied are taxonomy of birds of prey, energetic issues relating to aerial predation, and evolution of flight
Fuertes: Rails	Wetland ecology; taxonomy of Rails; reproductive ecology
Gould: Quetzal	Ecology of cloud forest; reproductive ecology and behavior of the Quetzal; taxonomy of the Trogonidae.
Gould: Spotted Bowerbird	Reproductive ecology and behavior; Australian birds; endemism.
Jonsson: Coastal Meadow Oystercatchers	Coastal meadow ecology; reproductive ecology and behavior.
Jonsson: Atrypa (Desire)	Marine coastal environment as habitat for birds; social behavior and flocking.
Keulemans: Pennula sandwichensis (Hawaiian Spotted Rail)	Extinction; endemism; flightlessness and evolution of flight

<b>Painting</b>	<b>Biological/Ecological ‘Story Line(s) ‘ Detected</b>
Keulemans: Pseudonestor xanthophrys (Maui Parrotbill)	Endemism; taxonomy and ecology of the Drepanidinae (Honeycreepers); conservation issues.
Lane: Boat-billed Heron	Ecomorphology and taxonomy of species; mangrove ecology.
Lane: Scarlet-banded Barbets	Ecomorphology and taxonomy of barbets (Family: Capitonidae); ecology of cloud forest; nature of discovery in non-experimental branches of science
Liljefors: Sea Eagle Chasing Eider Duck	Predation; marine coastal environment as habitat for birds.
Liljefors: Bean Geese at Sunset	Marsh ecology; social behavior and flocking; migratory behavior
Malick: High Prairie	Predation; ecology of prairie; conservation issues as an extension of the latter
Malick: Martial Eagle on Ground Hornbill	Predation; African birds; ecology of desert savanna
Martinet: House Sparrows	Coevolution of humans and birds; success of sparrows in urban environments
Martinet: Le Grande Martinet; Le Petit Martinet	Energetics of flight; reproductive behavior and ecology of swifts and martins; effect of human activity on populations
McQueen: Anna’s Hummingbird and Pacific Madrone	Energetics and physiology of hummingbirds; interdependence of birds and food plants
McQueen: Forest Owlet	Indian forest birds; nature of science - continual revision of beliefs in the face of new evidence; extinction and conservation issues
O’Neill: Galapagos Finches	Natural selection; endemism; island biogeography, adaptive radiation
O’Neill: Black-throated Blue Warbler	Reproductive ecology and behavior; life history from allocation of resources
Pratt: Brown Creeper	Interdependence of plants and birds; life-cycle of trees; concept of micro-niche
Pratt: Apapanes and Akepas	Endemism; island biogeography; adaptive radiation; conservation and extinction; interdependence of birds and food plants
Reinhold: Egyptian Vulture	Ecomorphology and energetics of scavenging birds; competition as force driving evolution of scavenging behavior.
Reinhold: Fiscal Shrike	Ecomorphology and taxonomy of species; predation and food chains; African birds



Thorburn: Gyr Falcon

Energetics of large predatory birds; home range; polar ecology

Thorburn: Blue Tits on a Teasel

Interdependence of plants and birds; concept of micro-niche

Weatherly: Carpenterian Grasswren

Desert ecology; limiting factors; endemism

Weatherly: Campbell's Fairywren

Taxonomy of Maluridae and nature of discovery in science; ecology of cloud forest; endemism

Whereas ecological realism and the information thus contained or implied is an important factor in the amount of information contained within a narrative ornithological image, there is a potential inherent problem that the attention given to background or behavioral interactions may lead to less information about the actual bird, i.e., that the morphological information about the species portrayed may be obscured. Thus one item in the section of the rubric examined the degree of information resolution contained within the each painting, rated the ecological realism of the painting on a Likert scale, and then asked if ecological realism was gained at the cost of loss of clarity. Where the habitat was given as much or more attention than the birds by the artist, or the theme of the painting involved some ecologically significant behaviors or interaction, the painting was given a rating of 'strongly agree' that the work had a strong component of ecological realism. Paintings where extensive habitat details were included, but formed a distinct background to the major subject (the bird or birds) were classified as 'somewhat agree' on the item rating the degree of ecological realism, as were paintings including only specific habitat elements, such as identifiable and relevant vegetation, or prey items, in the absence of a full background. Where habitat details were relatively minimal, the painting was rated 'somewhat disagree' or 'strongly disagree' depending on the ecological importance of the details shown. For example, if background foliage was generalized and impressionistic, not contributing biological information, or the bird was simply shown perched upon a generic-appearing branch, the painting would be 'classified as 'strongly disagree' that it was ecologically realistic. As a final

result of this analysis, the paintings in the sample were classified into three categories, summarized in Table 5.8. Each painting in the sample was also placed into one of the following three categories:

- i) Those paintings possessing a high degree of ecological realism with no loss of information with respect to the bird portraits (Table 5.9)
- ii) Those paintings possessing a high degree of ecological realism but lacking in technical information about the bird (Table 5.10).
- iii) Those paintings containing information-rich species portraits but lacking some elements necessary for ecological realism (Table 5.11).

Table 5.9 lists those 26 paintings in this sample that were rated highly on both ecological realism and clarity and information content of the species portraits. Ecological realism can be achieved by a variety of means. Showing the birds in life-like postures rather than in strict canonical view (e.g., Thorburn's *Blue Tits* and Pratt's *Apapanes and Akepas*), showing a variety of views of a species (Jonsson's *Atra*), showing a small but telling detail near the bird (Thorburn's *Gyr Falcon* and Reinhold's *Egyptian Vulture*) or by extensive attention to details of characteristic vegetation, particularly that in the immediate vicinity of the bird subject. Even a painting intended as a portrait or plate (e.g., Reinhold's *Fiscal Shrike* and Fuertes' *Diurnal Birds of Prey in Flight*) can convey a strong sense of ecological realism and thus serve as ecological narratives as well as sources of ornithological data) if a small and telling detail relevant to the life of the bird (the insect prey in Reinhold's *Fiscal Shrike*, or the bone in his *Egyptian Vulture*) is provided and rendered in sufficient detail, or where realistic background is provided as context for a mixed species plate (e.g., Coe's *Western Shorebirds* and Fuertes' *Diurnal birds of prey in flight*).

There were five paintings in the sample in which ecological realism of the background and/or behavior portrayed was rated very highly, yet the ecological information transmitted tended to obscure the strictly ornithological content (Table 5.10). This subsection of the sample included some very evocative and dramatic works, such as the illustrations of predation in Malick's *High Prairie*, and Liljefors' *Sea Eagle Chasing Eider Duck*, the migratory behavior in Liljefors' *Bean Geese at Sunset*, or feeding behavior in McQueen's exquisite *Anna's Hummingbird*. In these, the very demands of the scene that the artist intended did not allow for either canonical or multiple views of the bird. It seems that sometimes there is a necessary compromise between portrayal of behavior and/or environment and the technical visual description of a specific organism. Users of this genre for informational purposes should be aware that the artist may have specific intentions and these may not encompass transmission of ornithological data.

The sample also contained eight plates and portraits in which ecological realism and information was definitely subservient to the morphological information about species (Table 5.11). Ecological information contained within these works tended to be implicit, such as the hint of the importance of hardwood forests in Catesby's *Passenger Pigeon*, or contained within a visual comparison, such as the carefully differentiated bill types in O'Neill's *Galapagos Finches*.

**Table 5.8. Classification of the sample of narrative ornithological paintings with respect to ecological realism and technical ornithological data**

Classification: Ecological Realism vs. Ornithological Data	Number of Paintings in Category	Percentage of Paintings in Sample in this Category
High in ecological realism without loss of technical information with respect to bird portrait(s). Details of analysis shown in Table 5.9	26 Paintings	65.0%
High in ecological realism but lacking technical information in bird portrait(s). Details of analysis shown in Table 5.10	5 Paintings	12.5%
Low in ecological realism but containing extensive technical information in the bird portrait(s).	9 Paintings	22.5%

Classification: Ecological Realism vs. Ornithological Data	Number of Paintings in Category	Percentage of Paintings in Sample in this Category
Details of analysis shown in Table 5.11		

**Table 5.9. Paintings within the sample of 40 narrative ornithological paintings rated as possessing a high degree of ecological realism with no loss of clarity with respect to the bird portraits**

Painting	Justification for Inclusion in Category
Audubon: Black-throated Guillemot, Nodded-billed Auk, Curled- Crested Auk and Horned-billed Guillemot	Clear bird portraits with detailed background showing general features of environment common to all four species of Alcid.
Audubon: Ivory-billed Woodpecker	Three clear portraits utilizing three different views of the same species, shown in realistic and evocative composition as they search for food in bark of decaying tree.
Bateman: The Return – Bald Eagle	Two clear portraits of both genders shown against realistic and evocative background of nest.
Bewick: The Rook	Clear and detailed engraving of individual depicted against detailed and evocative agricultural landscape.
Coe: Western Rock Shorebirds	Detailed canonical portraits of five species depicted against detailed local habitat and wider coastal environment.
Coe: Black-bellied Plovers	Detailed canonical portraits of six individuals of varying ages, seasonal plumages and gender depicted against evocative sandy beach habitat.
Eckelberry: Yellow-crowned Night Heron	Detailed canonical portraits of both sexes depicted against evocative mangrove swamp mangrove, and including prey item.
Fuertes: Rails	Clear portraits of three species of the Rallidae, depicted against evocative marsh grass background that serves as a common habitat for these birds.
Fuertes: Diurnal Birds of Prey in Flight	Detailed and clear portraits of eight species of birds of prey, depicted against evocative background of vegetated marsh and sky.
Gould: Quetzal	Clear ventral-canonical portraits of nesting pair depicted against evocative and detailed cloud forest background. Also detailed foreground vegetation.
Jonsson: Coastal Meadow Oystercatchers	Clear ventral portrait of oystercatcher chick depicted against detailed coastal meadow habitat.
Jonsson: Atr (Desire)	Five clear portraits of the Eider Duck utilizing five different views of the species, depicted against evocative background of coastal marine waters.

Painting	Justification for Inclusion in Category
Keulemans: <i>Pennula sandwichensis</i> (Hawaiian Spotted Rail)	Clear and detailed portraits of both sexes depicted against evocative and detailed local habitat.
Keulemans: <i>Pseudonestor xanthophrys</i> (Maui Parrotbill)	Two clear portraits showing two views of the species, with feeding behavior and details of characteristic vegetation providing a sense of ecological context.
Lane: Scarlet-banded Barbets	Two vivid portraits of one species, in which attentive postures of the birds and dramatic use of light and shade to convey the atmosphere of the cloud forest provide a subtle but distinctive ecological realism.
Malick: Martial Eagle on Ground Hornbill	Two clear and detailed portraits of two species, engaged in an interaction that provides a dramatic sense of ecological realism.
Martinet: Le Grande Martinet; Le Petit Martinet	Two clear portraits of two species shown against common habitat for nesting. Architectural details provide realism.
O'Neill: Black-throated Blue Warbler	Clear and detailed portraits of both sexes and nestlings, with nest and characteristic vegetation providing evocative ecological setting.
Pratt: Brown Creeper	Finely drawn and detailed bird portrait depicted upon evocative and equally detailed background of tree trunk with fungus and lichens.
Pratt: Apapanes and Akepas	Two clear portraits of two species where the large and detailed inflorescences of the surrounding vegetation provide a strong sense of ecological realism.
Reinhold: Egyptian Vulture	Detailed and clear portrait where the clean-picked bone at the bird's foot and a few details of foreground vegetation are sufficient to provoke a sense of ecological realism.
Reinhold: Fiscal Shrike	Detailed and clear portrait where the prey item near the branch on which the bird perches and a few details of leaves on that branch are sufficient to provoke a sense of ecological realism.
Thorburn: Gyr Falcon	Detailed and clear portrait where a feather from a previously ingested prey item near the talons provokes a sense of ecological realism, which is supported by an evocative landscape.
Thorburn: Blue Tits on a Teasel	Two portraits showing two views of the species against an exquisitely detailed background. The lifelike postures of the feeding birds and minutely rendered details of the plant material convey a strong sense of ecological realism.
Weatherly: Carpenterian Grasswren	Clear and effective portrait of the Grasswren in a lifelike

Painting	Justification for Inclusion in Category
Weatherly: Campbell's Fairywren	<p>posture against an evocative desert background. Few background elements, but those shown are carefully detailed.</p> <p>One clear and detailed canonical portrait supported by a head-on partial view of the bird in a second portrait. Extensive habitat details of surrounding forest vegetation convey a strong sense of ecological realism.</p>

**Table 5-10. Paintings within the sample of 40 narrative ornithological paintings rated as possessing a high degree of ecological realism, but not information-rich respect to the bird portraits**

Painting	Justification for Inclusion in Category
Gould: Spotted Bowerbird	Postures of birds convey the interest and interaction between the pair, and nicely rendered habitat details in foreground give a real though delicately drawn sense of ecological realism. However, the sketchy nature of the bird portraits provides little morphological data about the species.
Liljefors: Sea Eagle Chasing Eider Duck	The drama of an incipient predation event, and evocative coastal landscape provide ecological realism, but the dorsal view of the White-tailed Eagle, and waves obscuring the fleeing Eider Duck do not allow for data-rich bird species portraits.
Liljefors: Bean Geese at Sunset	The action of the geese flying in to join the individuals waiting in the flock already at the roosting grounds, and the evocative portrayal of a marsh at sunset provide a powerful sense of ecological realism. However, the individual portraits of the birds are somewhat impressionistic, lacking the clarity required for a strict ornithological portrait.
Malick: High Prairie	Dramatic intensity of a critical moment of predation provides ecological realism, as does the attention to detail given to the prairie, but the postures and size of bird subjects do not allow for clear and detailed portraits.
McQueen: Anna's Hummingbird and Pacific Madrone	Interaction between bird and food plant provides ecological realism but not an information-rich portrait of the bird, which is relatively small compared to the plant material.

**Table 5.11. Paintings within the sample of 40 narrative ornithological paintings containing information-rich species portraits but lacking elements necessary for ecological realism.**

Artist/Title	Justification for Classification
Bateman: Three Ostriches on an Egg	Three lively and detailed portraits showing different postures but no ecological context provided except for the egg as background.
Bewick: Great Auk	Detailed portrait with some habitat elements, but insufficient to give strong sense of ecological realism.
Catesby: Heron, Eft, Chigoe, Cockroach	Elegant and detailed series of portraits of both Great Blue Heron and typical prey items. Plenty of ecological information provided but the composition presents these elements more as a visual list than an ecological scene.
Catesby: Passenger Pigeon	Clear and accurate canonical portrait with important habitat elements (oak leaves and acorn) shown in background, but importance of these implied rather than explained.
Eckelberry: White-eared Puffbird	Exquisitely detailed portrait that was originally an illustration to a new species report in the Auk, but lack of supporting ecological elements.
Lane: Boat-billed Heron	Assured and evocative portrait that lacks sufficient habitat elements for classification as ecologically realistic.
Martinet: House Sparrows	Two detailed canonical portraits illustrating both sexes. Urban background is indeed a common place to view these birds and an important element in the species' success, but appears in this painting as merely decorative rather than realistic.
McQueen: Forest Owlet	Graceful and detailed portraits of two individuals, with two views provided that together show all aspects of the species. Forest background is a little too impressionistic and undifferentiated for ecological realism.
O'Neill: Galapagos Finches	Clear and detailed series of portraits intended as a list for visual comparison, very descriptive but lacking habitat elements to enable ecological realism and explanation.

Integrity of the narrative ornithological paintings with respect to qualitative and quantitative aspects of the subject matter portrayed.

Determination of qualitative correctness of the birds portrayed in the sample of narrative paintings was carried out by referring to authoritative published descriptions of the species in the ornithological literature. No outstanding qualitative errors with respect to the bird subjects were detected; a predictable situation given that each artist is or was a distinguished ornithologist in his own right.

Tufte's criteria for qualitative integrity in scientific graphics also include an insistence that decoration free of content be eliminated (Tufte, 1983). The sample of narrative paintings was reviewed for inclusion of background elements or other phenomena that lacked ornithological or ecological relevance.

Thirty-five of the forty (87.5%) paintings in the sample were found to contain either strictly ornithological data, or background elements such as vegetation, prey items, or landscape details that contributed to knowledge of the bird species depicted. Thus in the majority of paintings, the emphasis is upon content and data. The remaining five paintings in the sample contained some aspect or elements that might be judged 'decorative'. However, as discussed below, these features can be justified by their contribution as an aesthetic hook, or by contributing to a sense of the ecology of the species. Bateman's *Three Ostriches on an Egg* might be considered a decorative work, with the birds actually painted upon an ostrich egg. However, the egg functions as an aesthetic and educational 'hook' and provides a potential gateway for stimulation of questions about reproductive ecology and behavior of the ostrich. Bewick's *Rook* depicts an agricultural scene in the background, which though technically irrelevant in ecological terms, does show the context in which the rook population boomed, for this is one of the species upon which human activities have had a positive impact. Martinet's



*House Sparrows* and *Le Grand Martinet*; *Le Petit Martinet* both depict their bird subjects against a detailed architectural background. However, the House Sparrow is now essentially dependent upon urban environments – Dan Lane comments that this species has actually co-evolved with humans (Lane, 2005). Likewise, the nest cavities provided by human constructions have contributed to the continuing success of populations of the House Martin and the Common Swift.

Gould’s *Spotted Bower Bird* shows a rather dramatic scattering of bleached bones in the foreground, that are not technically relevant to the ecology of the species, or the courtship ritual depicted. These elements are nonetheless evocative of the harsh desert environment in which the birds live. Reinhold’s *Egyptian Vulture* also depicts bones in the foreground; these are used to ‘tell the story’ of the feeding ecology of this scavenging species. Reinhold employs a similar technique in other portraits, such as that of the *Fiscal Shrike*, where a grasshopper in the foreground waits to be stabbed by the formidable bill of this small bird. Table 5.12 details the analysis of the background of each painting in the sample, and indicates how seemingly decorative elements may be justified in terms of the artist’s apparent purpose and the ecological or ornithological ‘story’ that is implied by the work.

**Table 5.12. Detailed analysis of backgrounds: justification of the decorative elements in narrative paintings in terms of the artist’s apparent purpose and the implied ‘story’ of the painting.**

Painting	Justification of Background and Decorative Elements
Audubon: Black-throated Guillemot, Noddy-billed Auk, Curled- Crested Auk and Horned-billed Guillemot	Landscape elements in background place these species of the Alcidae in their ecological and geographical context
Audubon: Ivory-billed Woodpecker	Foreground detail of recently dead tree supports ‘story’ of the species’ specific feeding requirements, and provides an effective framework within which a number of individuals are shown from different vantage points.
Bateman: Three Ostriches on an Egg	The ostrich egg on which the birds are painted is relevant to the ‘story’ of this unusual bird, since it is the largest egg of extant bird species, and acts as an aesthetic hook, also giving a three-dimensional element to the portrait.
Bateman: Bald Eagle – The Return	The foreground and background elements support the

Painting	Justification of Background and Decorative Elements
	story of the male eagle returning to the nest without food, and the danger to the eagle population as prey populations diminish as a result of human activity.
Bewick: The Rook	Landscape providing background to the portrait contains decorative elements such as farmhouse, fences, scarecrow, but these can be justified by their relevance to the agricultural context in which the rook populations boomed. Trees in distant background are important for nesting.
Bewick: Great Auk	A straightforward portrait with a background showing the North Atlantic coast, visually describing the habitat and geographic range of this extinct species.
Catesby: Passenger Pigeon	Oak leaves and acorn in foreground directly relevant to the foraging habits of the Passenger Pigeon and to the 'story' of the species' eventual demise.
Catesby: Heron, Eft, Chigoe, Cockroach	All elements directly relevant to the feeding ecology of the Great Blue Heron.
Coe: Western Rock Shorebirds	Foreground elements frame portraits and provide relevant information about the feeding ecology of the five species; landscape in background indicates the wider environmental context of the Pacific coast.
Coe: Black-bellied Plovers	Simple background of sandy shore places this species within a typical habitat and does not detract from the visual comparisons between seasonal and age-related plumages that form the 'story' of the painting
Eckelberry: White-eared Puffbird	Straightforward portrait – no background elements included.
Eckelberry: Yellow-crowned Night Heron	Foreground elements support feeding ecology of the species; background elements describe typical habitat and indicate geographic range while not detracting from the comparison between sexes that forms the primary theme of the painting
Fuertes: Rails	All the background elements support the 'story' of the typical habitat of this family; a flooded meadow or shallow marsh.
Fuertes: Diurnal Birds of Prey in Flight	The few decorative background elements included support the overall theme of aerial predation in this group of birds and the environments in which they find prey.
Gould: Quetzal	The foreground detail describes the nesting behavior and habitat of the Quetzal, while the background places the species in a wider environmental context – all elements support the story of an introduction to a rare and exotic species.

Painting	Justification of Background and Decorative Elements
Gould: Spotted Bower Bird	The bleached bones and animal debris scattered in the foreground are somewhat decorative, but support the story of the bower-building and courtship ritual of these birds. By underscoring the barren and arid environment in which these birds live, the energy expended in the gathering of materials to construct the bower is highlighted, and by implication, so is the role of sexual selection.
Jonsson: Coastal Meadow – Oystercatchers	Detailed habitat of coastal meadow of northern Europe with flowers indicating season, provides an informative setting for the story of the hatching and juvenile life-stages of this ground-nesting species
Jonsson: Atra (Desire)	No elements are wasted in this story of the form and behavior of the Common Eider in a typical northern Atlantic marine coastal environment, where five individuals (including both sexes) are shown from a variety of vantage points. Social behavior – flocking in this unprotected habitat – is a subtext.
Keulemans: Hawaiian Spotted Rail	A straightforward detailed bird portrait surrounded by characteristic vegetation that indicates a typical habitat of the species.
Keulemans: Maui Parrotbill	A straightforward detailed bird portrait surrounded by characteristic vegetation that indicates a typical habitat of the species.
Lane: Boat-billed Heron	Straightforward portrait of an unusual bird– no background elements included.
Lane: Scarlet-banded Barbets	Straightforward portrait of a recently discovered species, with evocative but impressionistic cloud forest foliage in background that serves to frame the birds.
Liljefors: Sea Eagle chasing Eider Duck	Strong but simple Northern Atlantic coastal background provides an uncluttered context for the ‘story’ of predation
Liljefors: Bean Geese at Sunset	Detailed marsh background and sky provides support for the story of diurnal feeding migrations in this species, in addition to providing some habitat information.
Malick: High Prairie	Portrayal of a vast, little-populated prairie adds intensity to the falcon’s hunt, and provides visual description of habitat of this species
Malick: Martial Eagle on Ground Hornbill	Portraits of the two species are framed within the context of a predator-prey interaction. The few habitat elements shown are just sufficient to indicate the general nature of the arid African open savanna in which the tale unfolds.
Martinet: House Sparrows	Essentially a portrait of the two sexes; the detailed architectural background is rendered in less saturated hues than the main subject and thus does not compete with it, also providing material for the background story of the

Painting	Justification of Background and Decorative Elements
	success of this species as it co-evolved with human populations.
Martinet: Le Grande Martinet; Le Petit Martinet	Two portraits against an architectural background that supports the story of primarily aerial species of birds that nest in crevices, such as those provided by human constructions.
McQueen: Anna's Hummingbird and Pacific Madrone	A fairly spare portrait of a hummingbird hovering around a characteristic food plant. Themes implied by this portrait include hummingbird physiology, conservation, role of Madrone as food plant for other wildlife, etc.
McQueen: Forest Owlet	Uncluttered and detailed portraits of a little known and recently re-discovered species. The background is a simple impression of tropical forest foliage, sufficient to place the bird in context without detracting from the main theme of introducing the 'new' species.
O'Neill: Galapagos Finches	Portrait of five species and their evolutionary relationship/adaptive radiation – there is no background necessary for this story, and none is shown.
O'Neill: Black-throated Blue Warbler	Background elements of nest, chicks, and characteristic old-growth hardwood forest support the theme of a visual description of this species and its habitat and reproductive ecology.
Pratt: Brown Creeper	The tree trunk and associated lichens and fungi provide a setting that displays the bird's behavior and provides habitat information while framing the portrait of the species.
Pratt: Apapanes and Akepas	The portraits of the two honeycreepers are shown with the common element of the 'Ohi'a in the foreground, a plant species on which both birds are somewhat dependent for food.
Reinhold: Egyptian Vulture	The decorative element of the scattered bones in the foreground of this portrait act as a clue to the 'story' of the species feeding ecology (scavenging).
Reinhold: Fiscal Shrike	A simple portrait with a grasshopper included in foreground to indicate the species feeding ecology. The grasshopper is rather large, which speaks to the use of the bill in the shrikes.
Thorburn: Gyr Falcon	A mountainous region of sub-Arctic Europe painted as background places this straightforward portrait of a majestic predator in an environmental and geographical context. A scrap of a prey item (feather) near the falcon's foot in the foreground indicates the feeding ecology, and the watchful look and the bare terrain suggest that only a powerful hunter would survive here.

Thorburn: Blue-Tits on a Teasel	A portrait of two birds feeding, commenting not only on their feeding ecology but only their ecomorphology, as the strong feet and bills and the compact form enable them to extract seeds from the Teasel. This is essentially a detailed portrait with story elements provided by details of the habitat.
Weatherley: Carpenterian Grasswren	A straightforward portrait, introducing the bird as it would be observed in a typical habitat.
Weatherley: Campbell's Fairywren	A portrait showing two birds from different vantage points in an unusual and complex habitat. This is unusual, since 'new' birds are generally described by bird artists in simple portraits. However, this endemic species is so restricted that the story of the habitat needs to be told, along with the physical visual description of the bird. The composition also allows the birds to be framed in realistic postures, as the viewer might actually see them in the field.

A further aspect of integrity in scientific graphics with which Tufte (1983) is much concerned is that of truthful representation of quantity and dimension. Quantitative (morphometric) correctness of the birds portrayed in the narrative paintings was assessed by reference to measurements in authoritative published descriptions of each species.

Morphometric ratios and proportions of bird species appeared to be correctly represented in 30 of the 40 narrative paintings; and in addition, background material gave visual references that provided an indication of the absolute overall size of the bird. The birds in nine of the remaining paintings were impossible to evaluate for quantitative correctness, mostly due to a lack of a canonical portrait of the bird, or a setting in which certain features of the bird were obscured (see Table 5.13). In only one painting was a minor quantitative error in morphology detected: John Gould's *Quetzal* depicts the tail feathers of the bird (described as 30" long by Pribor (1999) are shown slightly too long relative to the body length of the bird (described as 14" long by Pribor, 1999)

Tufte (1997) also cautions that appropriate scale must be maintained throughout a scientific graphic if quantitative integrity is to be achieved. Within the sample of narrative ornithological paintings, an appropriate sense of scale was automatically retained in the single species portraits with few background elements. The mixed species paintings, and those showing birds depicted against extensive habitat backgrounds were inspected for evidence of visual drifts in scale. The results may be summarized as follows: it was found that 10% of the sample consisted of single species portraits where scale was not an issue, approximately 70% retained an appropriate sense of scale in the visual narrative, and 20% allowed some visual drifts in scale. The majority of the scaling errors occurred since the bird was shown relatively large compared to features of the environment, sometimes a necessary compromise if details of the bird were to be represented with sufficient clarity. Drifts in scale between representations of different species did not occur.

**Table 5.13: Narrative ornithological paintings where quantitative errors were discerned, or where quantitative assessment was not possible.**

Painting	Quantitative Errors and Omissions Noted
Bateman: Three Ostriches on an Egg	Birds in proportion but painting on curved surface of egg makes overall quantitative assessment difficult.
Catesby: Heron, eft, chigoe, cockroach..	Impossible to evaluate overall quantitative correctness of heron, since only head shown. Bill and head are proportional, however.
Gould: Quetzal	Tail feathers appear a little too long relative to body; absolute measurements are reported as body length 14” and tail length 30”
Gould: Spotted Bower Bird	Sketchy nature of bird specimens with emphasis on ecological material makes quantitative aspects of bird difficult to evaluate.
Jonsson: Coastal Meadow – Oystercatchers	Painting is a little impressionistic to allow quantitative assessment of the oystercatcher chicks
Jonsson: Atrá (Desire)	Birds appear proportionally correct but lack of reference material in the open water background makes overall quantitative evaluation difficult.
Liljefors: Sea Eagle Chasing Eider Duck	Dorsal view of both species and lack of objects of known size in background makes quantitative aspects of birds difficult to judge.
Liljefors: Bean-geese at Sunset	Painting is a little impressionistic to allow quantitative assessment of the Bean-geese. However, goose size is fairly consistent and common knowledge, so this may not be a particular disadvantage.
Malick: High Prairie	Birds not shown in canonical view, and there is a lack of reference material of known size in the background, thus an accurate quantitative assessment of the birds is difficult here.
McQueen: Forest Owlet	Birds properly proportioned but absolute size of individuals difficult to judge in this painting due to lack of reference material of known size in background
Thorburn: Gyr Falcon	Bird properly proportioned but absolute size of individual difficult to judge in this painting, due to lack of reference material of known size in background

### Provision of Multiple Dimensions of Information

The third dimension of Tufte’s criteria for excellence in scientific graphics concerns the provision of multivariate information within the image. In this analysis, the rubric assessed the extent to which the variables of form, size, behavior, habitat, and distribution of the birds were included, and if and how the sample of paintings incorporated the dimension of time. Table 5.14

summarizes the types of information provided by the sample of narrative ornithological paintings.

Almost all paintings gave clear and detailed information about the form of the birds. Size was another matter; where indications of size were given, this was generally relative to a familiar object or organism also depicted in the narrative painting. Morphological adaptations included such avian features as: specialized bill type, long or short wing and tail feathers, toe arrangement, presence of bristles on the face, and/or notably cryptic or flashy coloration.

Direct information about behavior was deduced where birds were shown hunting, feeding, engaged in migration, courtship rituals, and in nesting or parenting activities. Habitat information was frequently provided directly by a full background, and included: Pacific rocky shores, arctic coasts, cloud forests, sandy coasts, coastal and inland marshes, rainforests, high prairie, arctic tundra, African savanna, desert grasslands, coastal and pelagic ocean environments, mangrove areas, mixed hardwood forests, and both agricultural and urban landscapes. This wide array of habitats depicted the diversity and both plasticity and specialization of avian lifestyles. When information about distribution of the species was available, this was without exception implicit, being deduced from the presence of certain vegetation, prey items, or landscape features included in the painting.



**Table 5.14. Summary of direct information about bird species and their ecology provided by the 40 item sample of narrative paintings.**

Category of Information	Number of Paintings In Sample Providing Information	Percentage of Paintings in Sample Providing Information	Reference Numbers Of Individual Paintings
Size	18	45.0%	1; 8; 9; 12; 13; 14; 16; 22; 26; 28; 29; 31; 32; 36 - 40
Form	38	95.0%	1- 22; 24; 26 - 40
Morphological Adaptations	33	82.5%	1 - 4; 6; 9 - 15; 19 - 23; 25; 26; 28; 29; 30 - 40
Behavior	28	70.0%	1; 2; 4; 5; 6; 8; 9 - 15; 19-21; 23 - 26; 28; 29; 32 - 36; 38 - 40.
Habitat	35	87.5%	1; 2; 4 - 7; 9; 10; 12 - 30; 32 - 35; 37 - 40
Distribution	9	22.5 %	1; 9; 12; 13; 15; 26; 29; 37; 40

Time is an important dimension of information in a scientific graphic, and Tufte claims that adding the dimension of time to an illustration can increase the informational capacity of an illustration tenfold (Tufte, 1983). This can be achieved by showing small multiples of the same object or phenomenon, allowing one data variable to change between multiples, such as in species comparisons, or comparisons of plumages by age or gender. In the case of ornithological illustration, birds can be indexed by other variables than plumage variation, such as behavior, gender, posture, and thus enforce small differences. An examination of the 40 narrative ornithological paintings in this sample showed that where the dimension of time was referenced by the work, this was achieved by one or more of the following strategies: depiction of motion, indexing species by age or seasonal plumages, or by explicit or implicit visual references to the life-cycles of organisms. These organisms included birds, invertebrate prey items, or flowering plants. Table 5.15 summarizes the approach to the problem of representing time throughout the

sample, and Tables 5.16 and 5.17 describe how the two most popular solutions – depiction of motion and reference to the life-cycle of some organism – were implemented by the artists.

Thirty-four of the paintings (85%) in this sample of ornithological narratives incorporated the dimension of time into the narrative. Table 5.15 summarizes the number and percentages of paintings that indicated or failed to indicate time, and how the treatment of time was manifested. Those six paintings that did not incorporate this dimension of information were exclusively static portraits of birds, where no motion or activity was incorporated into the portrait, and/or where the background information was not temporally informative, i.e., botanical material was not shown with fruits or flowers.

**Table 5.15. How the sample of 40 narrative ornithological paintings referenced the dimension of time.**

Strategy Utilized	Number of Paintings	Percentage of Sample	Reference Numbers Of Individual Paintings
Depiction of Motion	13	32.5%	3; 5; 13; 14; 18; 23; 24; 25; 29; 32; 34; 38; 40
Implied Life-Cycle of Organism	20	50.0%	1; 3; 4; 5; 7; 8; 12; 13; 15; 16; 19; 20; 26; 29; 33; 34; 35; 36; 37; 38
Variations in Age of Birds	3	7.5%	10; 13; 32
Implied Seasonality - birds depicted in breeding plumage	6	15.0%	1;6; 8;9;10;12
Multiple Strategies Utilized	10	25.0 %	3; 5; 8; 10; 12; 25; 29; 32; 34; 38
Time Not Referenced	6	15.0%	11; 21; 22; 27; 30; 39

Thirteen of the paintings incorporated the dimension of time by the depiction of motion. The treatments varied from the explicit – showing the birds in flight or swimming - to utilizing postures of the birds to indicate motion or imminent motion. In two cases (Liljefors' *Sea Eagle Chasing Eider Duck* and Malick's *High Prairie*), the explicit depiction of motion involved a detailed view of a predation event, freezing and dissecting a critical moment in time for both

predator and prey. Table 5.16 details how these paintings were perceived to accomplish incorporation of the dimension of time via the depiction of motion.

**Table 5.16. Thirteen narrative ornithological paintings in the sample in which the dimension of time was incorporated by depicting motion.**

Painting	How motion depicted or suggested
Bateman: Three Ostriches on an Egg	Ostriches shown running
Bewick: The Rook	Flock of rooks shown in flight in background
Fuertes: Rails	Postures of birds imply walking and pecking motion as they search for food
Fuertes: Diurnal Birds of Prey in Flight	All subjects shown in flight
Jonsson: Atra (Desire)	Some individuals swimming or landing on water
Liljefors: Sea Eagle Chasing Eider Duck	Eagle shown in flight and dropping upon frantically swimming duck with outstretched talons – an incipient predatory moment shown dramatically frozen in time.
Liljefors: Bean Geese at Sunset	Flock shown in flight as they return from feeding migration, in contrast to those previous arrivals shown watching and waiting
Malick: High Prairie	Prairie Falcon shown in flight, at moment of striking prey ‘an exquisite predatory moment’ frozen in two dimensions.
McQueen: Anna’s Hummingbird and Pacific Madrone	Hummingbird depicted in hovering flight around flower.
O’Neill: Black-throated Blue Warbler	Motion implied by parent alighting on branch with grub, and chicks begging.
Pratt: Apapanes and Akepas	Motion implied by the postures of both individuals, which are shown feeding
Thorburn: Blue Tits on a Teasel	Motion implied by postures of feeding individuals on the teasel
Weatherly: Campbell’s Fairywren	Motion implied by postures of birds as they search for food around the roots of a tree.

The most frequently employed strategy for representation of the temporal in these narrative paintings was inclusion of some visual reference to the life-cycle of an organism, whether directly by indicating nesting birds or including chicks in the scene, or implying the life-

cycle of other organisms, such as depicting fruiting or flowering plants, or inclusion of seasonally available prey items. Table 5.17 describes the use of life-cycles of organisms to incorporate the dimension of time in this sample of paintings. Some of these techniques are subtly suggestive rather than explicit, but still contribute to the sense of the scene having a distinct temporal position.

**Table 5.17. Twenty narrative ornithological paintings in the sample in which the dimension of time was incorporated by indicating or suggesting the life-cycle of an organism.**

Painting	Life Cycle Depicted or Indicated
Audubon: Ivory-billed Woodpecker	Life-cycle of tree implied – recently dead specimen with peeling bark shown
Bateman: The Return – Bald Eagle	Eagle’s nest implies life-cycle of birds
Bateman: Three Ostriches on an Egg	Egg as substrate for painting implies life –cycle of the birds
Bewick: The Rook	Recently ploughed and planted field indicates season
Catesby: Passenger Pigeon	Acorn indicates season
Catesby: Heron, Eft, Chigoe, Cockroach...	Depiction of seasonally available prey items provides temporal dimension
Eckelberry: Yellow-crowned Night Heron	Depiction of seasonally available prey item (adult crab) provides temporal dimension
Fuertes: Rails	Depiction of chicks implies life-cycle of birds
Gould: Quetzal	Nesting pair implies life-cycle of birds
Gould: Spotted Bowerbird	Courtship ritual implies life-cycle of birds, also bleached bones in foreground are suggestive of previous life at this site
Keulemans: Pseudonestor xanthophrys Maui Parrotbill	Plants in flower imply season
Keulemans: Pennula sandwichensis Hawaiian Spotted Rail	Fallen leaves and branches imply life-cycle of plants
Malick: Martial Eagle on Ground Hornbill	Stark contrast between dead Ground Hornbill and live Martial Eagle implies life-cycle of birds
McQueen: Anna’s Hummingbird and Pacific Madrone	Flowering Madrone implies season
Pratt: Brown Creeper	Fungi on tree and peeling bark imply age of tree and

	thus life-cycle
Pratt: Apapanes and Akepas	Flowering plants imply season
Reinhold: Egyptian Vulture	Bones of scavenged carcasses in foreground imply life-cycle, enlivens static portrait
Reinhold: Fiscal Shrike	Presence of prey item in foreground implies life-cycle by suggestion that a transition from life to death is imminent for this grasshopper, enlivens otherwise static portrait.
Thorburn: Gyr Falcon	Tiny feather from a previous prey organism by falcon's foot in the foreground indicate that a transition from life to death has recently occurred.
Thorburn: Blue Tits on a Teasel	Mature seeds of teasel imply season

Three paintings indicated time by varying the age of the birds. Two of these - Fuertes' *Rails* and O'Neill's *Black-throated Blue Warbler* - concurrently employed the indication of life-cycles by the inclusion of nestlings or juveniles and by depicting postures suggestive of motion or imminent motion. The third – Coe's *Black-bellied Plovers* – concurrently employed variations in the seasonal plumages of the birds to indicate time. Thus in a number of painting, time was indexed by changes in more than one variable. Table 5.18 lists the paintings in the sample where time was represented by more than one method.

Five of the paintings utilized variations in seasonal plumages to indicate the dimension of time. Again, three of these five concurrently indexed time by more than one variable (Table 5.18). As noted previously, Coe's *Black-bellied Plovers* also showed variations in the age of the subject, while Catesby's *Heron*, *Eft*, *Chigoe*, *Cockroach* and Eckelberry's *Yellow-crowned Night Heron* also indicated season by depiction of seasonally available prey items.

**Table 5.18. Ten narrative ornithological paintings in the sample in which the dimension of time was referenced by more than one strategy.**

Painting	Strategies utilized to reference time
Bateman: Three Ostriches on an Egg	Depiction of Motion/ Implied life-cycle
Bewick: The Rook	Depiction of Motion/ Implied life-cycle
Catesby: Heron, Eft, Chigoe, Cockroach...	Implied life-cycle/Implied seasonality
Coe: Black-bellied Plovers	Variations in age/ Implied seasonality
Eckelberry: Yellow-crowned Night Heron	Implied life-cycle/Implied seasonality
Malick: High Prairie	Depiction of Motion/ Implied life-cycle
McQueen: Anna's Hummingbird and Pacific Madrone	Depiction of Motion/ Implied life-cycle
O'Neill: Black-throated Blue Warbler	Depiction of Motion/ Implied life-cycle/Variations in age of birds
Pratt: Apapanes and Akepas	Depiction of Motion/ Implied life-cycle

#### Visual Comparisons Enforced or Suggested by the Narrative Ornithological Paintings

Tufte (1983) holds that one aspect of a superior scientific graphic is that it incorporates comparisons, demonstrating or inviting the awareness of differences. Differences are important to the information content of an image, since they add to the knowledge explicitly conveyed or implicitly suggested. Thus the more differences the more information conveyed. Subtle differences, or “the smallest effective difference” in Tuftean terms (Tufte, 1997, p.73) allow more differences, or a hierarchy of differences, and thus a greater richness of information about the phenomenon illustrated. In addition to adding to the information conveyed, differences also invite reasoning about cause and effect, and thus add to the explanatory power of the image. Strategies for displaying differences include: parallelisms to build connections by providing congruous structures across multiple images, and the consistent use of negative space to

reinforce these parallelisms and to allow the relevant information to become more coherent to the viewer.

Use of strict parallelism is not to be expected in narrative paintings, which are produced at least in part with the aim of aesthetic entertainment. However, as birds are depicted in typical naturalistic settings, it is reasonable to assume that certain comparative aspects will inevitably emerge as an inherent part of the scene. The sample of narrative ornithological paintings being analyzed as part of this study were examined for demonstrations of comparative aspects of behavior, ages and stages of maturity of birds, geographic variation within bird species, postural differences and gender differences. Miscellaneous differences – explicit or implied comparison that do not fall into any of the listed categories were also noted. The results of this analysis are described in Table 5.19 and summarized by Table 5.20.

Table 5.19. Comparative aspects discerned within a sample of 40 narrative ornithological paintings.

Painting	Nature of Explicit or Implied Comparisons	Explanatory Notes
Audubon: <i>Black-throated Guillemot, Noddy-billed Auk, Curled- Crested Auk and Horned-billed Guillemot</i>	Behavioral Miscellaneous - taxonomic	Fish-eating species shown perched on rock ready to dive; plankton feeders shown swimming Taxonomic differences between species of one family suggested.
Audubon: <i>Ivory-billed Woodpecker</i>	Behavioral Postural Gender	Individuals shown perching and actively feeding Three different postural views incorporated; male and female birds depicted
Bateman: <i>Three Ostriches on an Egg</i>	Postural Miscellaneous – Flight/Flightless adaptations	Three different views of ostrich in motion incorporated; different morphology of flightless vs. flying birds implied (short wings, strong legs, toes, necessity for defense mechanisms in absence of flight)
Bateman: <i>The Return – Bald Eagle</i>	Behavioral Postural Gender	Nest-guarding vs. hunting behaviors; two different postural views incorporated; male and female depicted
Bewick: <i>The Rook</i>	Behavioral	Rook shown perching in foreground,

Painting	Nature of Explicit or Implied Comparisons	Explanatory Notes
	Postural	background individuals feeding and flocking; species shown perched in canonical view and in flight
Bewick: <i>Great Auk</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Catesby: <i>Passenger Pigeon</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Catesby: <i>Heron, eft, chigoe, cockroach...</i>	Miscellaneous – prey items	Comparison of prey types that largely make up diet of Great Blue Heron other than fish
Coe: <i>Western Rock Shorebirds</i>	Miscellaneous – seasonal plumages; ecomorphological differences	Four species depicted in breeding and non-breeding plumages; also ecomorphological differences between a number of species occupying a similar but not identical ecological niche are apparent
Coe: <i>Black-bellied Plovers</i>	Gender Ages and Stages of Maturity Miscellaneous – seasonal plumages	Males and females shown; adults and juveniles; adult and juvenile plumages depicted
Eckelberry: <i>White-eared Puffbird</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Eckelberry: <i>Yellow-crowned Night Heron</i>	Behavioral Postural Gender	Birds shown standing and feeding; two different views of bird; male and female depicted
Fuertes: <i>Rails</i>	Behavioral Ages and Stages of Maturity Miscellaneous – Taxonomic differences	Birds shown standing and searching for food. Adult and young of Little Black Rail depicted Explicitly compares morphological differences between some members of same family (Rallidae) occupying similar ecological niche
Fuertes: <i>Diurnal Birds of Prey in Flight</i>	Miscellaneous – flight pattern and hunting behavior	Explicitly compares flight patterns, flight silhouette, and hunting behavior of this group of birds of prey
Gould: <i>Quetzal</i>	Behavioral Postural Gender	Birds shown perching and nesting. Two postures depicted Both sexes depicted
Gould: <i>Spotted Bowerbird</i>	Behavioral Postural Gender	Male displaying bower to passive female Two postures depicted Both sexes depicted



Painting	Nature of Explicit or Implied Comparisons	Explanatory Notes
Jonsson: <i>Coastal Meadow Oystercatchers</i>	Ages and Stages of Maturity Postural	Species shown as egg, while hatching, and downy chick. Two postures depicted
Jonsson: <i>Atra (Desire)</i>	Behavioral Postural Gender	Eider ducks shown landing, swimming, standing, sitting. Five postures depicted. Both sexes depicted.
Keulemans: <i>Pennula sandwichensis</i> (Hawaiian Spotted Rail)	Postural Gender	Two postures depicted Both sexes depicted
Keulemans: <i>Pseudonestor xanthophrys</i> (Maui Parrotbill)	Behavioral Postural Gender	Perching and feeding shown. Two postures shown. Both sexes depicted.
Lane: <i>Boat-billed Heron</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Lane: <i>Scarlet-banded Barbets</i>	Postural Gender	Two postures depicted Male and female depicted
Liljefors: <i>Sea Eagle Chasing Eider Duck</i>	Behavioral	Contrasts flight ability of aerial predator to prey species.
Liljefors: <i>Bean Geese at Sunset</i>	Behavioral Postural	Geese shown roosting and flying. Multiple views of the species shown.
Malick: <i>High Prairie</i>	Behavioral	Flying behavior of predatory and prey species strongly contrasted
Malick: <i>Martial Eagle on Ground Hornbill</i>	Behavioral	Strong contrast between aerial predator and ground dwelling bird
Martinet: <i>House Sparrows</i>	Postural Gender	Two postures depicted Male and female depicted
Martinet: <i>Le Grande Martinet; Le Petit Martinet</i>	Behavioral Postural	Contrasts different uses of buildings for nesting by the two species – Swift uses crevices, House Martin builds mud nest under eaves; Contrasts characteristic postures of the two species – Swift clings to vertical surfaces, Martin can stand on ledges
McQueen: <i>Anna's Hummingbird and Pacific Madrone</i>	Miscellaneous – size comparison between bird and plant material	Contrast between size of bird and leaves and inflorescence of Madrone (painted to scale) - emphasizes small bird
McQueen: <i>Forest Owlet</i>	Postural	Two postures depicted
O'Neill: <i>Galapagos Finches</i>	Miscellaneous: ecomorphological differences between related	Contrasts morphological differences between related species, especially bills,

Painting	Nature of Explicit or Implied Comparisons species	Explanatory Notes
		shows results of adaptive radiation.
O'Neill: <i>Black-throated Blue Warbler</i>	Behavioral Ages and Stages of Maturity Postural Gender	Nest guarding and feeding of young shown. Adults and nestlings shown Two adult postures and one characteristic of nestlings depicted Male and female depicted
Pratt: <i>Brown Creeper</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Pratt: <i>Apapanes and Akepas</i>	Miscellaneous – ecomorphological differences between species	Bill differences indicate the feeding specializations of two related species of honeycreepers, show results of adaptive radiation
Reinhold: <i>Egyptian Vulture</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Reinhold: <i>Fiscal Shrike</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Thorburn: <i>Gyr Falcon</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Thorburn: <i>Blue Tits on a Teasel</i>	Behavioral Postural	Shows plasticity of feeding behavior in this species. Two postures depicted
Weatherly: <i>Carpenterian Grasswren</i>	No differences shown or comparisons invited	Portrait of single individual – does not invite comparison
Weatherly: <i>Campbell's Fairywren</i>	Behavioral Postural	Fairywrens shown standing and searching for food. Two postures depicted.

**Table 5.20. Summary of categories of visual comparisons within a sample of 40 narrative ornithological paintings.**

Category of Visual Comparison	Number of Paintings in Sample Invoking Comparison	Percentage of Paintings in Sample Invoking Comparison
Behavioral	17	42.5%
Ages and Stages of Maturity	4	10.0%
Geographic Variation within Species	0	0%
Postural Differences	19	47.5%
Gender Differences	12	30.0%
Miscellaneous /Other	10	25.0%
No Visual Comparisons	9	22.5%

The majority (77.5%) of the paintings in the sample did invoke one or more visual comparisons, although the degree of parallelism and reinforcing congruous structures was very variable, suggesting rather than enforcing comparisons. On the whole, the artists utilized other composition techniques, and the comparison was presented in a fairly subtle fashion. Those paintings that were the original of plates in handbooks and field guides did tend to adopt the strategy of parallelism to a greater extent (Coe's *Western Rock Shorebirds*; Fuertes' *Diurnal birds of Prey in Flight*; O'Neill's *Galapagos Finches* are good examples, although Coe trades the quiet negative space recommended by Tufte for enforcing comparisons for a background rich in ecological information. Those narrative paintings that did not invoke comparisons were those where a single individual was the focus of the painting, the one exception to this being Catesby's *Heron, Eft, Chigoe, Cockroach*, where the variety of prey items depicted around the portrait of the bird formed the basis for the comparison.

In those thirty-one (42.5% of the sample) paintings that did invoke visual comparisons, the category of comparison seen most frequently was that of postural difference, a comparison

relatively easy to achieve when more than one individual of a species was depicted. It is not surprising that differences in posture are represented most frequently in the sample, as several artists interviewed this study considered a characteristic posture to be one of the most essential elements of the ‘jizz’ or gestalt of a species (Hunt, 2002a; 2003g; 2003h). However, in none of the ornithological narrative paintings was difference in posture the only comparative variable indexed; all also indexed some other difference of gender, behavior, age and stage of maturity, or some explicit or implied miscellaneous comparison.

Seventeen of the paintings depicted differences in behavior of the birds, showing two or more individuals of a species engaged variously in flying, perching, nesting, swimming, feeding, hunting, or fleeing a predator, e.g., Bewick’s *The Rook*, Jonsson’s *Desire*. Eckelberry’s *Yellow-crowned Night Heron*, Liljefors’ *Sea Eagle Chasing Eider Duck*, Malick’s *High Prairie*, O’Neill’s *Black-throated Blue Warbler*, and Thorburn’s *Blue Tits on a Teasel*. Naturally, the depiction of different behaviors automatically provokes a comparison of postures, resulting in considerable overlap between these two categories.

Almost one-third (30%) of the sample also showed male and female individuals of a species, an important comparative variable in avian species, where marked sexual dimorphism is common, as in Audubon’s *Ivory-billed Woodpeckers*, Coe’s *Black-bellied Plovers*, Eckelberry’s *Yellow-crowned Night Heron*, Gould’s *Quetzal*, Jonsson’s *Desire* (Eider ducks), and O’Neill’s *Black-throated Blue Warbler* (where the male and female differ to such an extent that John James Audubon was misled into believing these to be separate species). Again, many artists also depict the individual sexes in different postures or engaging in different behaviors, resulting in much overlap between the category of ‘Gender Differences’ and other categories. Four paintings – Coe’s *Black-bellied Plovers*, Fuertes’ *Rails*, Jonsson’s *Coastal Meadow Oystercatchers* and

O'Neill's *Black-throated Blue Warbler* - also displayed a comparison of species at different ages and stages of maturity. As Tufte (1983) cautions, differences indexed by more than one variable tends to undermine the viewer's attention being drawn to a specific area of difference. However, the tendency toward multiple visual comparisons adds to the richness of information provided by the image, possibly a necessary trade-off in this genre, where a complex portrait of the organism in its environment is a major aim of the artist.

Miscellaneous areas of comparison – comparisons not accounted for by the structure of the rubric - emerged in 25% of the paintings in the sample. Ecomorphological similarities and differences between different but closely related species are compared and contrasted in Audubon's painting of members of the Alcidae (*Black-throated Guillemot*, *Nobbed-billed Auk*, *Curled- Crested Auk* and *Horned-billed Guillemot*) and Fuertes' Rallidae plate (*Rails*), Coe's *Western Rock Shorebirds*, O'Neill's *Galapagos Finches*, and Pratt's *Apapanes* and *Akepas*. The Audubon and Fuertes paintings both explicitly compare and contrast ecomorphological characteristics of members of a single family occupying similar ecological niches, and Coe's *Western Rock Shorebirds* does likewise for members of two families in the order Characadiiformes. The O'Neill and Pratt paintings push the comparison beyond the explicit differences in characteristics, by implicitly posing the question of 'why' these differences came to be, in extremely closely related species confined to remote island chains, and pave the way for the construction of an explanation of these differences as being the product of an adaptive radiation in each case.

Other miscellaneous comparisons included a comparison of the species in breeding and non-breeding plumages i.e. in Coe's *Western Rock Shorebirds* and *Black-bellied Plovers*. Fuertes' comparison of flight silhouettes in his *Diurnal Birds of Prey in Flight* forces reasoning

about how flying behavior is related to different styles of predation, and Bateman's *three Ostriches on an Egg* subtly provokes the viewer to reason about relative adaptations to flight and flightlessness. The comparison of prey items forming part of the diet of the Great Blue Heron in Catesby's *Heron, Eft, Chigoe, Cockroach...* also poses a question to the more naive viewer, since this species of heron is generally considered to be a fish-eating bird, while the diet is in fact considerably varied and may include insects, reptiles and amphibians, small mammals, crustaceans, and some plant matter (Cornell Laboratory of Ornithology, 2000). Finally, in the painting *Anna's Hummingbird and Pacific Madrone*, Larry McQueen utilizes a scaled comparison of the size of a plant and bird to emphasize the small size of this hummingbird.

Visual comparisons of geographic variation within species were not present anywhere in this sample of paintings. This is not surprising due to the extreme difficulty of constructing a narrative scene that would sensibly incorporate individuals from different regions. Visual comparisons of this nature are more suited to the field guide or technical handbook.

Inclusion of Relational Phenomena That Enhanced the Ecological Content of the Paintings and the Lines of Ecological Interest and Reasoning that Might Potentially Be Stimulated by These Paintings

A major Tuftean criterion for integrity in a scientific graphic – and one especially relevant to the use of images in education - is the inclusion of relational phenomena, or variables that may be linked in some way to generate questions requiring causal explanations. A survey of the sample of ornithological narratives identified 25 relational categories of phenomena, which are listed in Table 5.21 along with the numbers and percentages of paintings in which the ecological phenomenon, variable, or concept was evident or implied. The number of relational phenomena identified in each painting is listed in Table 5.22, and examples of each category of phenomenon along with the reference numbers of works in which these were discerned by the

author and expert panel are provided in Table 5.23. Since many of the relational categories overlap, some paintings illustrate concepts and variables directly, while in others implicit phenomena emerge as the bird or habitat is studied further, little serious quantification is attempted here.

However, all paintings contained from 1-17 relational possibilities, with a mean of 7.4 (SD = 3.85; 90% confidence interval: 6.38-8.42) and a median number of 7 explicit or implicit ecological variables depicted, in addition to the visually descriptive ornithological information provided by the bird portraits. The four most frequent relational phenomena offered by the narrative paintings were: limiting factors to bird populations: explicit depiction of environments outside the continental U.S. and thus unfamiliar to many viewers; implied and explicitly depicted interdependencies of birds on other organisms (prey, and plants for food and nest sites), and explicit depictions of behavior (where the question ‘why’ follows naturally, and frequently leads to evolutionary explanations). Almost half the sample of paintings (45%) invited a consideration of conservation issues and human impact upon the environment.

Detailed discussion of every relational possibility inherent in each of the 40 paintings is outside the scope of this chapter, however, those identified by the author and validated by the expert panel are described in Table 5.23. However, it is worthwhile to examine those paintings that contained the greatest numbers of relational possibilities.

Surprisingly, a painting originally designed as a plate for a field guide to Ecuador – John O’Neill’s *Galapagos Finches* offered the most extensive relational possibilities. Illustrating five related species of finches, and with very few habitat elements depicted, the painting explicitly depicts comparative ecomorphology, implies how biodiversity results from adaptive radiation as a result of natural selection, demonstrates niche partitioning as a result of competition, and

exemplifies an approach to biology framed in terms of Darwinian principles. Implicit in the painting are notions of a common ecological community, the geography of the Galapagos Islands, conservation issues resulting from global climate change and/or human impact on the environment, and the question of limiting factors to finch populations on the islands. The subtext of the development of Darwinian ideas also invites a consideration of the nature of science.

Two further examples of narrative paintings found especially rich in relational possibilities for consideration by the viewer are Gould's *Quetzal* and Martinet's *Le Grande Martinet; Le Petit Martinet*. Martinet's portrait of a Common Swift (*Apus apus*) and the House Martin (*Delichon urbica*) against a background of an urban rooftop invites consideration of a number of related phenomena. The portraits explicitly describe the ecomorphological adaptations of the two species, showing the long wings and flight feathers geared to almost continuous flight, four toes pointing forward allowing gripping of vertical surfaces but not perching, and the tiny bill with a wide gape for trawling of vertical insects. These considerations of form and function segue into those of energetics and physiology: the inability to perch forces parent birds to leave the nest for several days in the event they must skirt a tropical depression (Royal Society for the Protection of Birds, 2005) and the young respond with a state of torpor, with considerably reduced respiration and body temperature. The adaptations to continuous flight also invite an exploration of long-distance migration (behavioral ecology) and the nesting sites at which the birds are depicted suggest suitable cavities for nesting as a limiting factor to populations (along with the availability of insects above 50 meters), competition for nest sites and the adverse effects on populations when urban centers undergo substantial modernization (human impact)



Gould's *Quetzal* also immediately invites consideration of limiting factors (here availability of suitable trees with cavities for nesting); and also natural selection (via sexual selection and mate choice) and coevolution – a little research reveals to the viewer that the frugivorous species is a major seed disperser of selected plants. The background also encourages speculation about the nature of the cloud forest habitat and related conservation issues. These exemplary descriptions of some of the relational phenomena that emerge from a considered viewing of these three paintings typify an approach that might be used with any other item in the sample to mine its informational and educational potential.

Table 5.21. Twenty-five ecological concepts and variables identified as relational aspects within the sample of 40 narrative ornithological paintings.

	Ecological variable or concept identified	Number of paintings in which ecological variable or concept was identified	Percentage of sample in which ecological variable or concept was identified
1	Limiting factors	23	57.5
2	Geographic region (outside continental U.S.)	21	52.5
3	Interdependence of species	20	50.0
4	Behavioral ecology	19	47.5
5	Conservation issues	18	45.0
6	Human impact upon environment	18	45.0
7	Evolution	17	42.5
8	Food webs	17	42.5
9	Niche concept	16	40.0
10	Predator-prey interactions	16	40.0
11	Ecomorphology	15	37.5
12	Range or distribution	12	33.4
13	Extinction	10	25.0
14	Reproductive ecology	10	25.0
15	Biogeography	8	20.0
16	Competition	8	20.0
17	Succession and recovery	8	20.0
18	Ecological communities	7	17.5
19	Life histories; r/K concept	7	17.5
20	Nature and history of science.	6	15.0
21	Energetics and environmental physiology	5	12.5
22	Energy flow and carbon cycling	5	12.5
23	Biodiversity	4	10.0
24	Darwinian principles as a framework for biology	4	10.0
25	Introduced species/exotics	3	7.5

**Table 5.22. Number of explicit and implied ecological concepts and variables identified as relational aspects in each of the 40 narrative ornithological paintings.**

Artist/Painting	Number of relational aspects discerned
Audubon: Black-throated Guillemot, Nodded-billed Auk, Curled- Crested Auk and Horned-billed Guillemot	7
Audubon: Ivory-billed Woodpecker	4
Bateman: Three Ostriches on an Egg	7
Bateman: The Return – Bald Eagle	8
Bewick: The Rook	5
Bewick: Great Auk	8
Catesby: Passenger Pigeon	4
Catesby: Heron, eft, chigoe, cockroach...	1
Coe: Western Rock Shorebirds	6
Coe: Black-bellied Plovers	3
Eckelberry: White-eared Puffbird	5
Eckelberry: Yellow-crowned Night Heron	7
Fuertes: Rails	5
Fuertes: Diurnal Birds of Prey in Flight	4
Gould: Quetzal	14
Gould: Spotted Bowerbird	9
Jonsson: Coastal Meadow Oystercatchers	2
Jonsson: Atrā (Desire)	3
Keulemans: <i>Pennula sandwichensis</i> (Hawaiian Spotted Rail)	9
Keulemans: <i>Pseudonestor xanthophrys</i> (Maui Parrotbill)	11
Lane: Boat-billed Heron	5
Lane: Scarlet-banded Barbets	7

Artist/Painting	Number of relational aspects discerned
Liljefors: Sea Eagle Chasing Eider Duck	12
Liljefors: Bean Geese at Sunset	2
Malick: High Prairie	6
Malick: Martial Eagle on Ground Hornbill	8
Martinet: House Sparrows	1
Martinet: Le Grande Martinet; Le Petit Martinet	15
McQueen: Anna's Hummingbird and Pacific Madrone	10
McQueen: Forest Owlet	11
O'Neill: Galapagos Finches	17
O'Neill: Black-throated Blue Warbler	9
Pratt: Brown Creeper	5
Pratt: Apapanes and Akepas	10
Reinhold: Egyptian Vulture	9
Reinhold: Fiscal Shrike	6
Thorburn: Gyr Falcon	10
Thorburn: Blue Tits on a Teasel	6
Weatherly: Carpenterian Grasswren	12
Weatherly: Campbell's Fairywren	13

**Table 5.23. Relational phenomena and ecological concepts identified in the sample of narrative ornithological paintings.**

Relational Phenomenon or Ecological Concept Identified	Examples of Phenomenon Or Concept	Made Explicit in Paintings #	Implied by Paintings #
Ecomorphology; Adaptations; Form and Function	Adaptations for swimming, diving, predation; cryptic coloration of ground dwellers; countershading in seabirds; toe arrangements; bill morphology relative to feeding ecology; facial bristles of insectivores; tail length; adaptations to particular flying needs	1; 4; 11; 13; 14; 15; 18; 21; 23; 25; 28; 31; 33; 37; 38	
Behavioral Ecology	Courtship displays; selection and mate	4;10;11; 12;14;	28; 29; 32

Relational Phenomenon or Ecological Concept Identified	Examples of Phenomenon Or Concept	Made Explicit in Paintings #	Implied by Paintings #
	choice; nesting behavior; parental care and reproductive allocation; function of flocking behavior; feeding behavior and hunting; scavenging; diurnal and seasonal migrations; territoriality	15; 16; 17; 18; 21; 23; 24; 26; 32; 33; 40	
Biodiversity	Loss of biodiversity; species abundance of Neotropics; natural selection and adaptive radiation; diversity of polar regions vs. tropical diversity patterns	31; 40	19; 22
Biogeography	Geographic restriction; allopatry, endemic species; subspecies; speciation	31; 34; 39; 40	15; 16; 34; 19;
Communities	Mixed hardwood forests of temperate regions; freshwater marsh; rocky shore; mangrove community; tidal marsh; coastal meadow; cloud forest; high prairie; tussock grasslands; desert savanna; wet tropical forest	15; 40	9; 23; 30; 31; 35
Competition	For space – organizing principle of rocky shore community; for nest holes – limiting factor for many cavity nesting species; for food with large predators and mutually exclusive home ranges as result; niche partitioning as evolutionary response; evolution of scavenging behavior; competition for light amongst plants and effect upon birds	9; 15; 31; 40	23; 28; 30;35
Conservation Issues	Seabirds and oil pollution; declines in food fish populations; hunting and egg vulnerability Bald Eagle recovery issues; White tailed Eagle and pesticide residues; human predation and disturbance Mangrove communities and aquaculture interests Quetzal – habitat destruction/poaching Endangerment of Hawaiian endemics by exotic species High prairie conservation/ agriculture Swifts – architectural modernization Indicator species – Martial Eagle Galapagos Islands – global climate change issues Loss of habitat to agriculture Loss of hummock grasslands to pasture		1; 4; 6; 12; 15; 19; 20; 23; 25; 26; 28; 30; 31; 32; 34; 37; 39.
Darwinian Principles as	Explicit illustration of results of	31; 34	33; 26

Relational Phenomenon or Ecological Concept Identified	Examples of Phenomenon Or Concept	Made Explicit in Paintings #	Implied by Paintings #
Framework for Scientific Ideas	adaptive radiation; species concept; current evolutionary debates		
Energetics and Environmental Physiology	Energetic cost of flight; allocation of resources to sexual display; torpidity in swifts; hummingbird metabolism; energetic requirements of large predators; controlled hyperthermia in ostriches; size constraints	3; 29	15; 28; 37
Energy Flow in Ecosystem	Plankton – fish – birds Transfer of terrestrially fixed carbon to ocean in mangrove areas; dung-eating in vultures	4; 12; 13; 23; 35	
Evolution	Evolution of flight and flightlessness; endemism; natural selection and adaptive radiations; coevolution with plants and humans; evolutionary relationships between families of birds; species concept; sexual dimorphism and evolution of reproductive behavior.	3; 6; 13; 16; 22; 28; 31; 32; 35; 39; 40	15; 19; 20; 26; 29; 31;
Extinction	Extinct species, those previously believed extinct, and those critically endangered include: Great Auk; Ivory-billed Woodpecker; Passenger Pigeon; Hawaiian Spotted Rail; Maui Parrotbill; White-tailed Eagle; Forest Owlet; Akepas; Carpenterian Grasswren	1; 6; 7; 19; 20; 30; 34	2; 23; 39
Food Webs	Food webs in open oceans; carbon cycling with respect to decaying trees; trophic web of freshwater marsh and mangrove swamps; transfer of fixed carbon between oceanic and terrestrial environments; food web in tropical forest; scavengers as trophic equivalent of top predators.	3; 6; 13; 16; 22; 28; 32; 35; 39; 40	15; 19; 20; 26; 29; 31;
Geography (outside continental U.S)	Areas depicted include: Alaska, Aleutians, and Bering Sea; Newfoundland; African savanna; rural England; Greenland; arctic Scandinavia; Northern Eurasia; South America and Galapagos Islands; India; Australia; and New Guinea; Hawaiian Islands	1; 5; 15; 16; 20; 23; 24; 26; 30; 34; 35; 36; 37; 39; 40	3; 11; 21; 22; 31; 38
Human Impact on Environment and Populations	Positive and negative effects of humans include economic exploitation of species by humans; introduction of	5; 28; 37	1; 2; 4; 7; 16; 19; 20; 23; 25; 29; 31; 34; 35; 38; 39

Relational Phenomenon or Ecological Concept Identified	Examples of Phenomenon Or Concept	Made Explicit in Paintings #	Implied by Paintings #
Interdependence of species	<p>exotic species and effects on bird population; degradation of habitat by draining of wetlands and clearing of forests; pesticide residues and marine pollution; provision of extra food by agricultural activity, landfills, and birders' feeder stations; provision of nest cavities by buildings in urban areas.</p> <p>Explicit and implied interdependencies include: dependence of birds upon suitable trees for food and nest cavities; complex food webs such as those in the mangrove ecosystems; coevolution of specialized frugivores (e.g., the Quetzal) and certain fruiting trees; dependence of ground nesters (e.g., the Spotted bowerbird) on understory shrubs; complex predator-driven interdependencies in rocky shore ecosystem; bottom-up dependencies such as plankton affecting Bald Eagle dependencies; populations of Hawaiian endemics dependent upon distribution of 'Ohi'a tree.</p>	<p>5; 8; 9; 12; 23; 28; 29; 30; 34; 37; 38; 40</p>	<p>1; 2; 4; 10; 15; 16; 35; 36</p>
Introduced Species/Exotics	<p>Implicit in sample is story of how predation from Norway rats and mosquito-borne diseases affected Hawaiian endemics; how non-native insects negatively affecting Eastern Hemlock and thus bird populations in United States.</p>		<p>19; 20; 32</p>
Life History; reproductive allocation; r/K concept	<p>Topics that emerge include egg size vs. clutch size; energetic investment in nesting and parental care; asynchronous hatching; reproduction rates of large predators; cavity nesters sharing niche in terms of nesting times.</p>	<p>3</p>	<p>6; 17; 20; 21; 26; 30</p>
Limiting Factors	<p>Ivory-billed Woodpecker area-dependent on large continuous tracts of softwood trees, with availability of recently dead and newly decaying wood; Yellow-billed Night Heron ; thought to be an area-dependent species, thus habitat degradation and elimination, and food availability regulate population numbers (Monfils, 2004); many endemic species (Quetzal; Hawaiian Honeycreepers)</p>	<p>4; 5; 15; 23; 24; 28 (nest sites); 29; 33; 37; 40</p>	<p>3; 11; 12; 21; 27; 28 (insects); 30; 31; 32; 34; 36; 38; 39;</p>

Relational Phenomenon or Ecological Concept Identified	Examples of Phenomenon Or Concept	Made Explicit in Paintings #	Implied by Paintings #
	dependent on specific food plants with which they have co-evolved; cavity nesters (e.g., Forest Owlet) limited by suitable trees for nesting.		
Nature and History of Science	In multi-species works, birds may be organized by a variety of scientific ideas – taxonomy, diversity, or Darwinian principles. Nature of discovery in non-experimental sciences; continuous revision of ideas in science (re-discovery of ‘extinct’ species; re-classification of species) as new evidence is presented.	31	7; 9;30;40; 22;
Niche	Specialized feeding niches (e.g., Quetzal, Ivory-billed Woodpecker; hummingbirds); species- specific niches in complex environments (e.g., rocky shore); niche partitioning (e.g., in aerial predators); concept of micro-niche (Brown Creeper; Blue Tits)	1; 5; 14; 15; 20; 21; 28; 29; 31; 34; 35; 38; 40	7; 9; 23;
Predator-Prey Interactions and Population dynamics	Man as significant predator (e.g., Great Auk); prey availability and population dynamics of large aerial predators; extinction as result of introduced predators (e.g., Hawaiian endemics).	4; 8; 12; 14; 23; 25; 26; 36	6; 10; 7; 9; 18; 19; 28; 37
Range/Distribution	Remnant populations (e.g., Ostrich, Maui Parrotbill, Akepa); area dependence and home range (Yellow-crowned Night Heron; Black-throated Blue Warbler); expansion of range due to increased food supply (e.g., hummingbirds, Blue tits); limits of specialized habitat (e.g., Carpenterian Grasswren; Campbell’s Fairywren); territoriality (e.g., Fiscal Shrike).	40;	3; 12; 14; 20; 28; 29; 32; 34; 36; 37; 39;
Reproductive Ecology	Clutch size; reproductive rate; egg predation and ground nesters; energetic costs of parental care; limitations upon nest sites; colonial nesting and pair bonds; asynchronous hatching; costs of territoriality	4; 16; 28; 32; 35;	11; 20; 30; 37; 39;
Succession and Recovery	Effects of slow community recovery after forest clearing (e.g., Forest Owlet, Quetzal); effects of inappropriate fire regimes upon bird habitat (e.g., Spotted Bowerbird; Carpenterian Grasswren; Anna’s Hummingbirds); decaying wood	2; 9; 12; 33	16; 29; 30; 39;

critical as food source (e.g., Ivory-billed Woodpecker; Brown Creeper); species feeding on marine benthos ultimately affected by climate-driven disturbances (e.g., Plovers, Yellow-crowned Night Heron).

The importance of relational phenomena within the narrative images lies in the lines of reasoning and the questions that may potentially be stimulated in the viewer; thinking that is developed later in this chapter when the educational potential of this genre is discussed. The fourth section of the rubric asked how each work might provoke thought in the viewer in a general sense, and also attempted to determine the “why”, “how”, “what” and “where” questions suggested by each painting.

Seventeen particular lines of questioning were identified from the sample of narrative paintings. The number of paintings from which each specific question could be inferred is summarized below in Table 5.24. The questions provoke the identification and explanation of causal factors and mechanisms including adaptations, energetics, evolution; population dynamics, and geography.

Table 5.24. Questions suggested by the sample of narrative ornithological paintings that require the construction of causal explanations.

Implied Question:	Number of Paintings	Reference numbers of exemplary paintings
‘Why are these birds shown together?’ (in multi-species paintings) or ‘What is the relationship between these birds?’ or ‘What other birds are related to this species?’ (in cases of unusual species).	10	1; 8; 9; 13; 14; 21; 22; 28; 31; 34
‘Why does this species possess this particular morphological feature?’ (explanations of bills, feet; features of plumage; facial bristles, etc.)	24	1; 2; 3; 4; 6; 8; 11; 12; 15; 18; 19; 20; 21; 23; 25; 28; 30; 31; 33; 34; 35; 37; 38
‘Why’ do some species engage in flocking behavior while others are primarily solitary?’	7	5; 10; 18; 23; 24; 25; 37
‘Why does plumage vary with respect to age, season, or sex in some species	11	1; 2; 4; 9; 10; 12; 15; 18; 19; 27; 32
‘What is going on in this scene?’ – explain the behavior of	17	2; 4; 5; 8; 14; 16; 17; 18; 20; 23;



Implied Question:	Number of Paintings	Reference numbers of exemplary paintings
the birds in an ecological context.		24; 25; 26; 28; 29; 35; 38
‘What is significant about flight or flightlessness in this scene?’	11	1; 3; 6; 13; 14; 19; 23; 25; 26; 28; 29
‘What is significant about egg-laying in this group of vertebrates?’	4	3; 16; 17; 32
‘What might be the limiting factor(s) to the population of this species?’	17	1; 2; 4; 7; 8; 10; 14; 18; 20; 21; 22; 23; 24; 25; 26; 35; 37
What are the implications to population success provoked by a species’ nesting behavior – on the ground, in cavities, in trees, etc?’	8	4; 13; 15; 16; 17; 19; 28; 32
‘What are the implications of a species investing in a significant degree of parental care?’	6	4; 13; 15; 15; 17; 32
‘What impact have humans had upon this species’ population?’	6	4; 5; 20; 27; 28; 34
‘What was the cause of this species becoming extinct or almost extinct?’	5	2; 6; 8; 19; 30
‘What functions does countershading in seabirds, or cryptic coloration in other birds, serve?’	13	1; 6; 9; 10; 13; 17; 18; 19; 24; 28; 33; 37; 39
‘What are the implications of limited defenses against predation in flightless birds and those that dwell and/or nest upon the ground?’	10	1; 3; 6; 13; 15; 16; 17; 19; 26; 39
‘What interdependence between the bird species and other organisms exists?’	15	2; 3; 7; 8; 9; 12; 14; 15; 20; 23; 29; 33; 34; 36; 39
‘Where is this species found?’	17	1; 6; 12; 15; 16; 17; 18; 20; 22; 23; 25; 26; 30; 34; 35; 39; 40.
‘How many prey are required to support this predator and what implications does this have for the size of this species’ home range and population size?’	9	4; 8; 14; 23; 25; 26; 35; 36; 37

The paintings were also examined for manifestations of clear correlations, and also for evidence of causal relationships that would explain such correlations. Finally, in those paintings that were classifiable as visual confections, I asked how the viewer might be able to construct meaning or explanations from what might otherwise be an arbitrary juxtaposition of images.

The explicit correlations in the paintings were limited for the most part to the ecomorphological; that is, demonstration of the link between form and function. Thirty-seven of the paintings in the sample showed or implied ecomorphological correlations, some of which are described in Table 5.23. For example, the phenomenon of countershading in seabirds, the webbed feet of swimming birds; the typical toe arrangement of perching birds and the talons of birds of prey; the link between diet and bill morphology; the short stubby wings of flightless birds and those that live in a complex forest habitat versus the large wingspan and long primary feathers of aerial predators were plentifully illustrated in the sample. One painting – John O'Neill's *Black-throated Blue Warbler* – suggested the important correlation between degree of parental care in birds and the energetic investment of this species in egg-laying and nest building. The elaborate bower depicted in John Gould's *Spotted Bowerbird* also implied the energetic investment necessary for reproductive success, and his *Quetzal* made the link between the availability of tree cavities for nesting and reproductive success that is critical to many forest species.

An additional four paintings implied a correlation between the success of a species and the availability or activities of another – specifically, those of man. Bewick's *Rook* implied the success of this species in areas where human agricultural activities provided a source of grain and easier access to worms and grubs in ploughed fields. Catesby's *Passenger Pigeon* is shown with an acorn, implying the dependence of this species upon hardwood forests (if this species had not been made extinct through over-hunting, its demise was almost certain due to extensive clearing of forests for agriculture). Bateman's *The Return – Bald Eagle* depicts how the lack of available food fish (a result of over-harvesting by industry and marine pollution) may impact the

reproductive success and population growth of the Bald Eagle. Martinet's *House Sparrows* implies the success of this species due to human activity and urbanization.

Nine of the 40 paintings in the sample were loosely construed as 'visual confections', i.e. they depicted species juxtaposed in combinations or conditions that are unlikely to be seen in nature. Six of these were classified as visual lists. Audubon's painting of four species of the Alcidae (Auks); Coe's plate of Western shorebirds; Fuertes' painting of three species of the Rallidae (Rails) and his plate of diurnal birds of prey; Martinet's *Le Grande Martinet*; *Le Petit Martinet*; O'Neill's plate of Galapagos Finches were all essentially works comparing different but related avian species while placing them visually within a common functional ecological setting. A slightly different visual list was found in Catesby's *Heron, eft, chigoe, cockroach...*, which listed various prey items of the Great Blue Heron.

Bateman's *Three Ostriches on an Egg* definitely qualified as a visual confection that did not function as a visual list. Meaning, or an explanation of this painting can be constructed by the viewer on several levels, concerning the evolution of the egg, the evolution of flightlessness and the adaptations this required for the species' success, but does require some instruction in, or research upon, the subject matter. However, all paintings judged as visual confections were rated as highly effective scientific graphics, since searching for the commonalities between the species in the visual list, and the importance of the egg-as-substrate in the Bateman painting inherently encourages the generation of meaningful questions.

The final item of the rubric used to analyze the narrative paintings in terms of adherence to Tufte's (1983; 1990; 1997) criteria for effective scientific graphics asked for a general rating of the success of each painting in the clear portray of complex subject matter. All paintings in this sample were rated extremely successful by this criterion. However, it should be remembered

that all artists responsible for these works are or were expert naturalists and acknowledged masters of the genre, and it does not necessarily follow that any narrative ornithological work necessarily be rich in scientific content, or encourage scientific reasoning.

## Section Two: Ornithological Plates from Field Guides as Scientific Graphics

### Selection and Analysis of the Sample of 40 Plates

In addition to analysis of narrative ornithological paintings for adherence to Tufte's (1983; 1990; 1997) criteria for excellence in scientific graphics, this study also examined ten sets of plates from four popular field guides to bird for their adherence to these same standards. Nine families of birds, and one multi-family group of birds of prey were selected for analysis (see Table 5.25). These selections were made in conjunction with an expert panel, consisting of senior members and officials of active birding groups in south Louisiana (Appendix F). The plates selected for analysis are intended to represent groups of birds with varied morphology and occupying a wide range of ecological niches, and that the author and panel considered either common enough through the United States to be of interest to a large audience (e.g., the mockingbirds and thrashers) and/or were of some intrinsic aesthetic or ecological interest (e.g., hummingbirds, birds of prey, and wading birds). Each group of birds was also given extensive coverage in each of the four field guides selected for review.

The rationale behind our specific final choices was as follows. The birds of prey are a related group of diurnal carnivores including vultures, hawks, eagles, kites, harriers, falcons, and the osprey. This group tends to arouse the interest of casual birdwatchers due to their size and distinctive flying behavior. These birds also pose interesting identification problems for the

beginner since they are frequently only seen at a distance and flight patterns and overall silhouette may be the only clues to species.

The Corvidae – crows and jays – were selected because the group is well known and easy to observe, and is of extra interest due to their large vocal repertoires, often-sighted habit of caching seeds for later recovery, and their easily observed cooperative social behavior.

Unusual morphology, unique flying behavior, incandescent colors and relatively fearless behavior make the family Trochilidae (hummingbirds) almost unique in its ability to attract and engage the casual observer. They are also of biological interest due to their fast metabolism, unusually promiscuous behavior among birds (Gill, 1985), and ability to undergo torpid states for short periods of time. Hummingbirds are increasingly easy to observe as their range is expanding in some species at least partially due to extra resources becoming available as interested birders provide feeding stations (Peterson, 2000; 2006).

The Laridae (gulls, terns, and skimmers) are included as an easily and commonly observed group of marine birds. This family has a worldwide distribution, attract interest with elaborate displays both flying and on the ground, and is of behavioral interest due to colonial nesting practices. The long-legged waders (family Ardeidae; herons and bitterns) were selected as an additional group of water-dependent birds that are easily observed in shallow-water habitats, as large and attractive birds of ecological importance, and as indicators of a healthy environment (Ramel, 2005). The Anatidae (waterfowl) are also widespread, easily observed in a variety of rural and urban habitats, and also of economic interest in many areas where hunting is a major leisure interest.

The New World family Mimidae – mockingbirds and thrashers - are ground-foraging songbirds familiar to many residents of the United States. This group is noteworthy for the

“unequalled variety and volume of their song” (National Geographic Society, 2000, p. 354), and some of these species are of interest to the casual bird student for their extensive mimicry of other birds, and of other sounds in their habitat. The Picidae (woodpeckers and sapsuckers) were selected for their charisma, and the ease with which they may be observed - or identified by their distinctive calls - in forested areas throughout the United States and worldwide. They are also important to avian ecology in general, since the holes they drill typically provide nesting sites for a suite of other bird species, in which the availability of such cavities is typically the factor limiting their populations (Roberson, 2000).

Pigeons and doves – family Columbidae – were included as a widespread family typified by the domestic pigeon, and thus easy for many viewers to engage with. They are also of interest due to the great spatial memory exhibited during migration, and their ease of domestication (Gill, 1995). The final family selected was the Parulidae, or wood-warblers. The Parulidae are a large family (114) species of migratory neo-tropical songbirds, 50 of which breed in the United States, and the spring arrival of these active and colorful songsters is a noteworthy phenomenon observed annually by many people not otherwise given to bird observation. They are also of great interest to the ecological research community, and field and laboratory studies of this family have contributed to advances in community ecology, speciation, and feeding behavior.

**Table 5.25. Families of birds selected for analysis as field guide plates, and their corresponding coverage in each of four popular bird guides.**

Group/Family of Birds	Coe (2001)	National Geographic Society (2002)	Peterson (1984)	Sibley (2000)
Birds of Prey (Accipitridae; Cathartidae; Falconidae; Pandionidae)	Pp. 44-51	Pp.102-109	Pp. 150 – 171	Pp. 104-133
Crows and Jays (Corvidae)	Pp. 104-5	Pp. 312-319	Pp. 206-209	Pp. 350-61
Hummingbirds (Trochilidae)	Pp. 92-93	Pp. 264-270	Pp. 186-187	Pp. 295 -302

Gulls, Terns, and Skimmers (Laridae)	Pp. 74-81	Pp. 194-223	Pp. 84-99	Pp.202-240
Long-legged Waders (Ardeidae)	Pp. 54-58	Pp.56 -63	Pp.100-105	Pp. 57-65
Mockingbirds and Thrashers (Mimidae)	Pp.112-113	Pp. 354-57	Pp. 218-219	Pp. 410 - 415
Pigeons and Doves (Columbidae)	Pp. 82-83	Pp. 234-239	Pp. 180-181	Pp. 254-261
Waterfowl (Anatidae)	Pp. 32-43	Pp.66-101	Pp.42-73	Pp. 70-103
Woodpeckers (Picidae)	Pp. 92-97	Pp. 274-285	Pp. 188-193	Pp. 306-319
Wood Warblers (Parulidae)	Pp.122-134	Pp. 366-390	Pp. 230-51	Pp. 424-450

The plates for each group of group or family of birds, in each of the selected field guides, were analyzed using the rubric in Appendix C. The results of the analysis of this sample of plates are reported below by grouping Tufte's criteria under the following sub-headings:

- i) Integrity of the plates with respect to qualitative and quantitative aspects of the birds depicted, appropriate scaling of the different species portrayed on a single plate, and adherence to the principle of proper context.
- ii) Multivariate information contained within each plate: i.e. if the variables of form, size, behavior, habitat, and distribution of the birds were included and how they were presented to the viewer.
- iii) Inclusion of relational phenomena that enhanced the ecological content of the plates and the lines of ecological interest and reasoning that might potentially be stimulated.

Integrity of the Plates with Respect to Qualitative and Quantitative Aspects of the Birds Depicted, Appropriate Scaling of the Different Species Portrayed on a Single Plate, and Adherence to the Principle of Proper Context.

In terms of Tufte's first major axiom concerning the use of data ink, all plates examined devoted 75 –100% of the area either to the birds, or to portraying relevant ecological information about the species illustrated. Thus, as might be expected, field guides maximized their use of data ink.

Certain assumptions were made with respect to principles of integrity within the four field guides. Since field guide plates are extensively and intensively reviewed by a panel of expert ornithologists selected by the publisher, it seemed appropriate to regard the individual bird portraits as qualitatively correct, and also quantitatively correct with respect to proportions and morphometrics of each species.

Each mixed species plate was evaluated for visual drifts in scale between the species. Visual drifts in scale were not apparent in the plates, and the species in mixed species plates were generally scaled appropriately with respect to each other. There was, however, difference in how quantitative information about species illustrated was presented to the viewer, with Sibley (2000) directly labeling the illustrations with information about body and wing length, and the other three illustrators giving this information in a text paragraph about the bird. This same pattern continued where other aspects of information about the species were concerned, with Coe, The National Geographic Society, and Peterson providing information about form, field marks, behavior, and habitat within text on a facing page, while Sibley's textual information varied in its placement, sometimes on the same page under the species name, sometimes in small font at the bottom of plates, and sometimes in a text column on an adjacent page. All guides provided distribution information in the form of color-coded range maps. Sibley placed these at the base of



the relevant plate, Coe and the National Geographic Society provided these on facing pages, and Peterson placed all range maps at the rear of the book, although he did provide a brief verbal description of the bird's range in the text.

Table 5.26 summarizes how each field guide presented various categories of information to the viewer/reader. Peterson's information about all aspects of the bird tended to be the most succinct. Sibley sometimes gave extensive textual descriptions of morphology and field marks, but provided only very brief notes about behavior and habitat. Coe consistently described typical habitat, and gave relevant information about flight, diet, and nesting, as well as describing the bird's typical calls. The National Geographic Guide also provided this information, with some comments about a species' conservation status where appropriate, and overall gave more extensive textual description than did the other three guides. The National Geographic guide also provided verbal descriptions of the frequency of occurrence of a species in different areas of its overall range; the remaining three guides required that the viewer decode the range maps provided.

The final principle of integrity as described by Tufte (1983; 1990) is that of adherence to proper context, which in this instance translates as indicating how the organisms in a mixed species plate are related. All four publications satisfied this criterion, showing the various species arranged by taxonomic relationship (for the most part, birds on any given plate were members of the same subfamily). The National Geographic Society guide and Coe provided sufficient background elements to somewhat relate species by common habitat.

**Table 5.26. How various categories of information about each bird species were delivered to the viewer in each field guide.**

Information Category	Coe	National Geographic	Peterson	Sibley
Size	Body length and wing length described in text (facing page)	Body length and wing length described in text (facing page)	Body length described in text (facing page)	Body length and wingspan given under heading of species name on same page as illustration.
Form/ Adapt – ations/ Field Marks	Detailed description of form and field marks in text (facing page)	Detailed description of form and field marks in text (facing page)	Described briefly in text on facing page. Similar species also listed.	Described extensively in text, but location and amount of information variable.
Behavior	Flying behavior both illustrated and described in text on facing page. Some information about calls, nesting, and diet in text.	Flying behavior both illustrated and described in text on facing page. Fairly extensive information about calls, nesting, hunting behavior and diet in text. Conservation status included where appropriate.	Flying behavior illustrated in most cases, not verbally described. Voice described in text on facing page for each species. Brief notes on food given under heading of subfamily in text at top of facing page.	Variable. Brief notes on hunting behavior, flight patterns, migration, diet appear under generalized subheadings, which are not entirely consistent throughout the plates
Habitat	Described in text on facing page.	Described in text on facing page.	Briefly noted in text on facing page.	Amount and location of information variable.
Distribution	Color-coded range maps on facing page.	Color-coded range maps on facing page.	Briefly described in text on facing page; range maps provided at end of book.	Color-coded range maps on same page as illustration.
Frequency of occurrence	Not explicit. Viewer must decode range maps	Discussed in text	Not explicit - Viewer must decode range maps in rear of book	Not explicit. Viewer must decode range maps

Multivariate Information Contained Within Each Plate – Inclusion of the Variables of Form, Size, Behavior, Habitat, and Distribution of the Birds, and Related Issues of Concealment, Disinformation, and Noise.

Tufte (1990) insists that not providing the fullest possible information within a graphic is effectively concealment, or disinformation. Each plate within each group was evaluated in terms

of insistent emphasis on telling details, such that relevant small phenomena were not masked by the general architecture of the illustration; if information about the frequency of occurrence of the bird throughout its range was supplied (indicated by terms such as ‘rare’, ‘common’, or ‘winter visitor’); whether multiple and layered views of the species were provided; and if spatial parallelism was used effectively to enforce comparisons. A great deal of information can potentially be conveyed by a mixed species field guide plate, and finally, the plates in each guide were considered in terms of their noise factor, or the incorporation of elements that tend to divert the eye from content.

The authors and producers of the four field guides employed a variety of techniques to draw attention to small and important differences between the illustrations. Coe and the National Geographic Guide used extensive textual description of features of different species on a facing page and also emphasized such details on the actual portraits, by a combination of highlighting, use of saturated colors and a hierarchy of line weight. Peterson used arrows to insistently point out field marks that distinguish species, sexes, and stages of maturity. Sibley used a great deal of direct verbal labeling of important details on the actual illustrations. These two authors tended to utilize these systems of direct labeling as a substitute for visual hierarchies in the illustration itself.

Spatial parallelism - the practice of placing different views of a species (or different species of birds) within the eyespan, with the intent of forcing visual comparisons of important variables - was effectively used by Coe, the National Geographic Society, and Peterson. The National Geographic Guide utilized this strategy most effectively, especially for the age-related plumage differences important to identification of birds of prey, and also to compare differences between sexes in species where sexual dimorphism exists. The illustrations in this guide are the

products of several different artists (Malick; Pendleton; Schmitt), but a common arrangement was to enforce visual comparisons by actually overlapping the images to be compared, a technique demonstrating great compositional skill, especially as species were frequently shown within a habitat setting. Coe also used a detailed background for many species of these birds, placing the illustrations of comparative interest in such positions as to naturally draw the eye from one view or species to another. Peterson utilized overlap in his spatial parallelisms, and further emphasized the comparisons with his insistent arrow system. Sibley only made use of spatial comparison in his birds of prey plates when he compared age-related plumage differences. This author utilized even quantities of white space to separate the individual illustrations, with relevant differences noted by direct labeling.

All four guides were rated highly on their provision of multiple and layered views. Within the plates of birds of prey, both dorsal and ventral views of the bird in flight were provided, along with at least one detailed canonical portrait, enlarged head details and call-outs in some cases, as well as provision of visual information on sexual dimorphism, regional color morphs, and age-related plumage differences. The extensive amount of information provided for this group of birds did pose a problem of ‘noise’ – a plethora of information not effectively delivered due to the tendency of the eye to become diverted in an attempt to make sense of the different illustrations. Coe solved this problem by placing many of the birds within a landscape and using compositional techniques to lead the eye through the various views and species illustrated. The designers of the National Geographic plates and Peterson used overlapping portraits of comparable birds, and severely reducing the space between others such that the eye was not tempted to wander around the plate. Sibley provided a great deal of visual information but necessity for vertical movements of the eye throughout the plate, and occasionally movement

to another page, reduced the efficiency of its delivery. The amount of direct textual labeling on the illustrations in Sibley also contributed to the noise factor, as the viewer was constantly forced to switch between processing text and decoding the information in the portraits. Although the preceding remarks refer to the plates of the birds of prey, the same characteristic approach was utilized by each author for all groups of plates that were examined in the study.

### **Structural Approaches to Conveyance of Multivariate Information in the Field Guide Plates**

Tufte's concern about conveyance of the multivariate nature of the subject matter, and the degree of resolution with which information is presented was translated in this context into seven criteria. The rubric enquired how the important dimension of time was indicated in the plates; which visual comparisons were invited by the plates; if a micro-macro approach to the plates – where detail is displayed within the context of larger data structures – and the Particular-General-Particular strategy was utilized; how the hierarchy of details within the illustration was indicated; the degree of ecological realism offered by the plate design; and the degree to which the plate served as an orderly sequence of visual paragraphs describing the species illustrated.

Time was indicated in all four publications by depiction of motion: one or more illustrations of each species in flight were shown and by varying the age of the birds. Life cycles were also suggested by the depiction of prey items in some plates.

The micro-macro and particular-general –particular approach to plate design was evident in Coe and the National Geographic Society Guide, both of which used some habitat elements to provide a general architecture, with the individual species portraits providing essential detail. Hierarchy of detail within the portraits was provided by variation of line weight and subtle variations in color saturation by these two guides. Peterson and Sibley did not include habitat elements in their plate design, and micro-macro and particular-general-particular strategies were

not discerned here. These authors also relied more on direct labeling than visual hierarchies to indicate important details.

All plates in Coe, the National Geographic Guide, and Peterson were highly rated with respect to consistently inviting visual comparisons within species. These comparisons included those of behavior (between different flying behaviors such as soaring and hovering; perching, feeding, and nesting); ages and stages of maturity; gender differences; geographic variation within a species; and appearance of the same species as it assumed different postures (two to five different views of any one species were typically shown). Sibley continued to be something of an anomaly: as much and frequently more visual information was offered in the plates, but the positioning of the portraits on the plate, and sometimes on other pages, did not invite comparisons except by a committed viewer.

Due to the inclusion of habitat elements on the plates, Coe and the National Geographic Guide offered more of a sense of ecological realism, a sense that was most marked in the Coe guide – this illustrator included a significant amount of telling habitat detail. The Peterson and Sibley plates, though technically excellent, were not considered to convey a sense of realism. The fine compositional skills of Coe and the National Geographic Guide illustrators also resulted in the depiction of the species as an orderly visual sequence, for as the eye travels across these portraits-in-a-habitat, each individual portrait tends to be inspected in a sequence designed by the artist. Peterson's portraits were not placed within a habitat but the placement of different individual portraits in the same horizontal plane and generally within the eyespan resulted in an orderly visual sequence. Due to more random organization of the portraits, the Sibley guide did not relate a visual story as well as the other publications – once more, following the logic of the arrangement required effortful work on the part of the viewer.

### Inclusion of Relational Phenomena that Enhanced the Ecological Content of the Plates and the Lines of Ecological Interest and Reasoning that Might Potentially Be Stimulated

The ultimate aim of a scientific graphic should be to stimulate reasoning on the part of the viewer (Tufte, 1997), a process that is encouraged by the explicit display or implication of relational phenomena within the image. Plates in all four field guides were examined in terms of the relational phenomena and/or ecological concepts that were made explicit - or implied by – the selected plates, in addition to the technical information about the bird subjects illustrated delivered by these. Information contained in the text was also included in this analysis, since text is an integral part of the plates in these field guides. As with the narrative paintings of birds, the nature and extent of these relational phenomena is important for purposes of this study since it is these that provoke the formation of “How?”, “What?”, “Where?”, and “Why?” questions in the viewer, and may ultimately stimulate the construction of causal explanations. Table 5.27 summarizes the relational phenomena and ecological concepts/topics that were discerned within the sample of plates, and lists the particular sets of plates in which each topic was noted. Appendix I contains tables showing the detailed analysis of the plates by group or family of birds.

A total of 26 ecologically oriented concepts and topics were identified within the sample of plates (Table 5.27). This is a slight increase (one item) over the number of relational phenomena found within the sample of narrative paintings (Table 5.21), and many phenomena/topics discerned were common to both the field guide plates and the narrative paintings (seventeen ecological topics were common to both genres; see Chapter 6 for a list of the common phenomena). A major difference between the two genres of bird illustration was that in the field guide plates, supporting text and labeling frequently indicates phenomena (such as habitat and social behavior) that is shown directly in the narrative paintings. In both genres,

some concepts and topics were shown explicitly, while others required varying degrees of educated inference on the part of the viewer.

Relational aspects of phenomena that were illustrated or implied in all sets of the field guide plates included many topics pertaining to evolution, such as speciation and hybridization resulting from separation or overlap of range, and various co-adaptive relationships between birds and plants – the role of hummingbirds as pollinators is exemplary. Areas of population genetics were also represented in all plates; all groups of birds illustrated contained hybrids, color morphs including examples of albinism and leucism, or mosaics and intergrades. Natural selection could also be inferred from any plate showing sexually dimorphic birds, via the themes of female choice and sexual selection. Information upon range and distribution, with implied questions of biography was likewise contained explicitly in all plates, for all species illustrated.

Explicit examples of ecomorphology were naturally found in all plates, and in addition to the form and function relationships illustrated, these also had potential for encouraging reasoning about more general issues in ecology e.g., the functions of cryptic coloration, and of countershading in seabirds. Issues of taxonomy and taxonomic relationships are similarly inherent to all field guide plates. In some cases, the supporting text added to the theme by reporting issues of current difficulties in classification, such as the recent tentative reclassification of the Olive Warbler from the Parulidae into a new family (National Geographic Society, 2002, p. 390), an item that also reflects the continuous revision of ideas in science, and invites consideration of more recent tools of classification than the strictly morphological approach. Other ecological topics well-represented (by 80% or more of the plates), were those concerning the evolution of flight, and the mechanics of flight in birds with differing lifestyles (e.g., diurnal birds of prey vs. wading birds); foraging behavior (including niche partitioning,



caching, and the role of scavengers in the ecosystem), life-histories, and reproduction and reproductive ecology. The diversity of birds in the selected group of places was sufficient to provide examples of species along the r/K continuum, and the reproductive topics referred to by the illustrations and text includes the difference in predation upon nests in the open and those in cavities, generating a consideration of the energetic trade-offs (egg laying, nest building, and parental care) involved in reproductive success of a bird. Sixty percent of the plates also made reference to social behavior in birds, including the topics of flocking and interspecific associations, colonial nesting, cooperative breeding, and eusociality. Migration and issues of human impact, upon bird species and populations were explicitly referred to in fifty percent of the plates.

Other topics illustrated or implied by various plates in the sample were communication in birds, including the topics of territoriality and vocal mimicry, competition, conservation, energetic requirements of different avian lifestyles, extinction, habitat choice and niche partitioning, wetland ecology, and predation, including the key concept of top predators in an ecosystem. Coe (2001) and the National Geographic Society (2002) visually indicated representative habitat of a number of species. As a result, interdependence of species was suggested by illustrations where a number of birds of prey were shown clutching representative prey items in their talons, by illustrations of hummingbirds feeding at flowers, and the hint of the dependence of woodpeckers upon suitable trees.

Table 5.27. Summary of relational phenomena and ecological topics discerned in field guide plates, by family and guide.

Ecological topic or relational phenomenon discerned in plates	Plates (by group/family of birds) in which topic/phenomenon illustrated
Communication (including function and description of calls and songs; territoriality; vocal mimicry)	Crows and Jays Mockingbirds and Thrashers Wood warblers
Competition (derived from explanation of range, and feeding ecology; also intraspecific competition assumed from notes upon territoriality)	Birds of Prey Crows and Jays Gulls, Terns, and Skimmers Mockingbirds and Thrashers
Conservation issues (develop from illustrations of endangered species, notations upon habitat dependence)	Crows and Jays Wading birds Woodpeckers
Ecomorphology (form and function, including cryptic coloration and countershading)	All plates
Energetics – amount of food required to maintain lifestyle	Birds of prey Hummingbirds Waterfowl
Evolutionary questions relating to speciation and population genetics: species concept; issues of separation and overlap of range; geographic variation; co-adaptive relationships between birds and plants. Hybridization, color morphs, albinism and leucism, mosaics, and intergrades	All plates
Exotic (introduced) species	Pigeons and Doves Waterfowl
Extinction	Pigeons and Doves Waterfowl Woodpeckers
Fire Ecology	Crows and Jays
Flight: evolution, advantages, and mechanics;	Birds of Prey Gulls, Terns, and Skimmers Mockingbirds and Thrashers Pigeons and Doves Wading birds Waterfowl Wood warblers
Foraging behavior (including caching, role of scavengers in ecosystem; niche partitioning)	Crows and Jays Gulls, Terns, and Skimmers Mockingbirds and Thrashers Pigeons and Doves Waterfowl Wood warblers Woodpeckers
Habitat, habitat choice and niche partitioning	Crows and Jays

Ecological topic or relational phenomenon discerned in plates	Plates (by group/family of birds) in which topic/phenomenon illustrated Mockingbirds and Thrashers Pigeons and Doves Woodpeckers
Herbivory – role in ecosystem	Waterfowl
Human impact upon bird species (increases and decreases in range and population numbers)	Crows and Jays Gulls, Terns, and Skimmers Mockingbirds and Thrashers Pigeons and Doves Wading birds
Interdependence of species (from predator/prey relationships, and interdependencies of birds, invertebrates, and plants; relationship between birds and man)	Birds of Prey Hummingbirds Waterfowl Woodpeckers
Life histories (including r-K concept and delayed development, often from illustrations of sexually mature birds vs. immature birds)	Crows and Jays Gulls, Terns, and Skimmers Mockingbirds and Thrashers Pigeons and Doves Wading birds Waterfowl Wood Warblers Woodpeckers
Limiting factors (most frequently from explanations of range and/or issues of habitat dependence)	Birds of prey Hummingbirds Wading birds Woodpeckers
Migration and migratory behavior (sometimes from information in supporting text)	Gulls, Terns, and Skimmers Pigeons and Doves Waterfowl Wood Warblers Woodpeckers
Nature and history of science (from uncertainties in classification schemes)	Wood warblers
Natural selection (arises most frequently from sexual dimorphism, courtship and sexual selection, also from variation)	All plates except the Mockingbirds and Thrashers
Predation; Predator/prey dynamics	Birds of prey Wading birds
Range/Distribution (explicit) and Biogeography (implied)	All plates
Reproduction; reproductive ecology; trade-offs and investment in nesting and parental care; nest predation in open and cavity nest (from illustrations of nesting birds and in supporting text)	Birds of prey Crows and Jays Gulls, Terns, and Skimmers Mockingbirds and Thrashers Pigeons and Doves Waterfowl Wood Warblers Woodpeckers

Social behavior (including flocking and interspecific associations; colonial nesting, cooperative breeding and eusociality)	Crows and Jays Gulls, Terns, and Skimmers Pigeons and Doves Wading birds Waterfowl Woodpeckers
Taxonomy and taxonomic relationships– classification of birds into family, genera, species, and subspecies, use of morphometrics and molecular techniques (from supporting text)	All plates
Wetland ecology (habitat)	Gulls, Terns, and Skimmers Wading birds Waterfowl

### Overall Rating of the Sample of Field Guide Plates

The author and members of the expert panel consulted for this section of the study gave an overall rating to the plates within each publication with respect to their success as clear portrayals of complex subject matter, which is Tufte's (1997) ultimate criterion for a truly useful scientific graphic. Overall (Fleiss kappa = 0.89), Coe's plates and those of the National Geographic Guide were rated very highly as successful scientific graphics by Tufte's criteria. The compositional techniques and habitat elements provided as background stimulated more general ecological questions, while the individual portraits provided ample detail of the features of the birds. Peterson and Sibley were related moderately successful.

Peterson's ornithological information was clear, concise, and easy to retrieve visually, but the lack of supporting habitat elements eliminated some useful lines of reasoning. Sibley's guide contained extensive and detailed information about the birds, but again, the lack of background elements tended to confine the visual reasoning stimulated to the purely ornithological rather than more general ecological topics. This particular guide appears to serve best as a handbook for the committed viewer seeking detailed answers to ornithological and morphological questions that have been formulated previously.

### Section Three: How Might Ornithological Imagery Be Used Effectively In The High School And College Classroom?

In Section three the educational potential of both paintings and field guide plates was considered in relation to the ecological topics described by the American Association of Science's *Benchmarks for Scientific Literacy* (1993), contained within the environmental science coverage in the *National Science Education Standards* (NRC, 1996), and the most important concepts in ecology ranked by the British Ecological Society (Cherrett, 1989). Each painting and plate was evaluated by the rubric in Appendix D. The author's evaluations were scrutinized by two experienced science teachers (Appendix F.). The agreement between the author's evaluations and those of the reviewers yielded a Fleiss Kappa values of 0.84 ( $\alpha = 0.05$ ), indicating a satisfactorily high degree of agreement between the three raters.

The rubric first sought to evaluate the explicit or implied presence in each work of 20 concepts in ecology specified by the National Research Council, the American Association for the Advancement of Science, and the British Ecological Society as being highly important in terms of classroom education in biology. The percentage of paintings and plates in which each concept was illustrated or implied are listed in Table 5.28

**Table 5.28. Percentages of occurrences of concepts and topics important in ecology education within the sample of narrative ornithological paintings and the field guide plates.**

Recommended Ecological Concept	Percentage of narrative paintings where concept was illustrated or implied	Percentage of field guide plates where concept was illustrated or implied
Carrying Capacity	34%	50% (Birds of prey; wading birds; hummingbirds; waterfowl; woodpeckers)
Community	17.5%	40% (all families in Coe; six families in NGS)
Competition	20.5%	30%
Conservation of Resources	45.0%	30%
Ecological Adaptation	37.5%	100%

(The) Ecosystem	30.0%	35%
Ecosystem Fragility	25.0%	40% (wading birds; hummingbirds; waterfowl; woodpeckers)
Energy Flow	12.5%	
Environmental Heterogeneity	45.0%	100% (implied by information on distribution)
Food Chains/Webs	42.5%	20%
Human Impact	45.0%	50%
Interdependencies Between Species	50.0%	30%
Life-history Strategies	17.5%	50%
Limiting Factors	57.5%	50%
Mechanisms and Results of Evolutionary Processes	42.5%	100%
Niche	40.0%	25%
Population Ecology	27.5%	90%
Predator – Prey Interactions	27.5 %	20%
Species Diversity	0%	75%
Succession and Recovery	55%	20%

I discuss below how each of the recommended concepts might be accessed through an ornithological image. However, it should be noted that many concepts overlap as they are discussed in the context of these images, and there is a pronounced tendency for one topic or concept to segue into another.

### Carrying Capacity and Ecosystem Fragility

Carrying capacity of the environment is not illustrated explicitly, and it is difficult to conceive how this might be implemented. However, this concept is implied by illustrations representing distinct limiting factors in the environment, such as obligatory cavity nesting species such as the Forest Owlet or the swifts and martins, specialized frugivores such as the Quetzal, or other species dependent upon a limited food source such as the Ivory-billed Woodpecker. Images of large birds of prey in open landscapes – e.g., Liljefors' Sea Eagle, Malick's Prairie Falcon and Thorburn's Gyr Falcon – also pose the question of how large an area is required to support these birds in terms of prey availability. Bateman's poignant portrait of a male Bald Eagle returning without food to his waiting mate also provides an easy segue into a consideration of prey availability and thus carrying capacity. Field guide plates of birds of prey

may also conceivably be used to develop the concept of carrying capacity in the classroom, particularly those that include prey items in the illustration (Coe, 2001; National Geographic, 2002).

'Carrying capacity' is also an intuitive concept for estimating ecosystem fragility (Wood and Rydén 1992), a concept that can be explored utilizing plates and narrative paintings depicting examples of birds occupying delicately balanced systems such as mangrove swamps and other wetland habitats, cloud forest, and the Hawaiian archipelago. Among the groups of birds selected for the field plate sample, the wading birds, hummingbirds, waterfowl, and woodpeckers potentially provide material for developing the concept of carrying capacity and ecosystem fragility.

### Community

Ecological communities are explicitly indicated by paintings depicting birds against a detailed background where characteristic vegetation and/or other organisms are included. Eckelberry's White-crowned Night Heron and Coe's Western Rock Shorebirds are exemplary, as are Malick's High Prairie, Thorburn's Blue Tits on a Teasel, and Weatherley's Campbell's Fairywren. All of the field guide plates in Coe (2001), and those of the National Geographic Society (2002) for six of the ten groups of birds selected also included sufficient habitat elements to indicate the ecological community of which the bird is characteristically a member.

### Competition

Examples of competition can be mined from paintings and plates showing the results of the process of natural selection, as different species display adaptations to specialized feeding niches developed as the result of competition for food. John O'Neill's Galapagos Finches is a classic example. The idea of competition for space can also be developed via discussion of

environments where this is an organizing principle, such as Coe's Western Rock Shorebirds, and competition for light among plants arises from depictions of forested environments, such as shown in the cloud forest floor depicted in Weatherly's Campbell's Fairywren. Birds of prey and scavenging birds are frequently shown as solitary specimens in large expanses of landscape, which can be explained in terms of mutually exclusive home ranges occurring as a result of competition for food e.g., Thorburn's *Gyr Falcon*, Reinhold's *Egyptian Vulture*, Malick's *High Prairie* and *Martial Eagle*, and Liljefors' *Sea Eagle Chasing Eider Duck*. Within the sample of field guide plates, the idea of competition emerged from those plates depicting related species that occupy the same habitat and utilize many of the same resources, found in some plates of the wood warblers, wading birds, and waterfowl.

### Conservation

Conservation issues arise easily from a consideration of many of the narrative paintings and plates. Images of seabirds – e.g., Audubon's Alcid plate, Bateman's Bald Eagle, Bewick's Great Auk, Jonsson's *Coastal Meadow Oystercatchers*, and any of the plates of the Laridae (gulls, terns, and skimmers) – invite consideration of declines in food fish populations, hunting, and egg vulnerability. Plates of the Anatidae (Waterfowl) may provoke discussion of the conservation measures implemented by bag limits and seasonal restrictions upon hunting. Human predation and disturbance by habitat destruction for agricultural purposes or pesticide residues has affected a number of birds depicted in the sample – the Ivory-billed Woodpecker, sea eagle, cloud forest species such as the Resplendent Quetzal, and birds requiring undisturbed natural grasslands such as Campbell's Fairywren and the Prairie Falcon. Plates of birds dependent upon wetlands such as the long-legged waders (Ardeidae) are suited to discussions of wetland conservation. Plates of the woodpeckers (Picidae) show a group of bird dependent upon



sizable stands of hardwood trees, which offer food sources and nesting opportunities, and Audubon's Ivory-billed Woodpecker is a well known example of a bird which disappears when such habitat is reduced. The Passenger Pigeon (illustrated in the plates and the Catesby painting) is a species that would have declined due to forest clearing had it not first been exterminated by human predation.

The topic of conservation thus overlaps with that of extinction, and by extension, that of introduced – or exotic – species. Many endemic species of birds have become extinct or threatened due to the deleterious effects of introduced species. Within the sample of narrative paintings these are represented by the Hawaiian endemics painted by Keulemans, McQueen, and Pratt. In the sample of plates, examples of exotic species were seen within the waterfowl plates, and those of the pigeons and doves.

#### Ecological Adaptation, Energy Flow, and Food Webs

Examples of ecological adaptation may be found within almost any accurately executed bird image, by pointing out how bill morphology, feet, wing and tail shape and size, flight pattern or flightlessness are the result of adaptations to the environment. Energy flow in the environment and food webs are illustrated explicitly in any narrative painting that depicts plant or animal food items of birds, and the discussion may be led in the direction of carbon fixation by photosynthesis as the building block of complex organisms. Paintings and plates of birds feeding in marine environments provide examples of the transfer of carbon between the oceanic and terrestrial environments.

#### Ecosystem

The concept of an ecosystem as an area that contains organisms (e.g., plants, animals, bacteria) interacting with one another and their non-living environment is illustrated by the

majority of the narrative paintings containing background elements, and those field guide plates that contain certain habitat elements such as those found in Coe (2001) and the National Geographic Society (2002). The narrative images also illustrate that ecosystems can be of any size (e.g., the mountain range depicted in Thorburn's *Gyr Falcon*, the expanse of prairie in Malick's *High Prairie*, or the marsh of Liljefors' *Bean Geese at Sunset*, through the meadow depicted in Jonsson's Coastal Meadow Oystercatchers and the rocky shore detailed in Coe's *Western Rock Shorebirds*, through the single tree as ecosystem shown in Pratt's *Brown Creeper* and within the woodpecker plates of Coe (2001) and the National Geographic Society (2002).

#### Environmental Heterogeneity and Interdependencies Within Species

Environmental heterogeneity, or resource patchiness, potentially governs the actual frequency of occurrence of some bird species within their geographical range. This is exemplified within the narrative paintings by the Anna's Hummingbird (sufficient food resources), the Carpenterian Grasswren (limited to tussock grasslands within Southern Australia, and thus only known from eight locations), the Forest Owlet (limited by nesting cavities within old tropical hardwood forest) and the Resplendent Quetzal (limited by the availability of nest holes and the fruit trees upon which it is specialized within the cloud forest). Explanation of the factors that determine range and distribution of birds in many of the field guide plates can also be used to introduce the idea resource availability. Environmental heterogeneity and the distribution patterns of dependent species that this implies also invokes the interdependence of species, illustrated richly throughout the narrative paintings, and also in those plates (e.g., woodpeckers, hummingbirds, birds of prey) that show such associations between birds and other organisms.

## Human Impact

A considerable proportion of the species depicted in the plates and paintings examined have had their populations affected positively or negatively by human activities. Negative results of human activity include reproductive problems from pesticide residues (Bateman's Bald Eagle, Liljefors' Sea Eagle, and any of the plates of birds of prey); food shortages through industrial fishing, and issues of marine pollution (e.g., Bateman's Bald Eagle, Audubon's Alcids, Coe's Black-bellied Plovers and Shorebirds), direct predation upon birds or eggs that has historically affected bird populations (e.g., Catesby's Passenger Pigeon, Bewick's Great Auk, Liljefors' Sea Eagle, Thorburn's Gyr Falcon), introduction of exotic species (Fuertes', Keulemans', and Pratt's paintings of Hawaiian endemics) and habitat disturbances (e.g., Audubon's Ivory-billed Woodpecker, many plates and paintings of birds dependent upon wetlands).

Some positive effects of human activity upon selected bird species are also illustrated. Bewick's *Rook* depicts one species that benefited from the expansion of British agricultural activity due to increased food supply, as did Martinet's house sparrows in the face of the development of urban centers of population in Europe. Martinet's portrait of the Common Swift and the House Martin illustrate two species where availability of nest sites actually increased with human populations. Among the field guide plates, hummingbird populations have been known to increase with the rise of interest in hummingbird feeders, and the plates of pigeon and doves illustrate an entire group of bird that has historically coexisted successfully with man. Many of the species illustrated in the waterfowl plates have also benefited from sound management policies instituted by organizations representing hunting interests.

## Species Diversity

Species diversity – strictly speaking - is the number of different species in a particular area (species richness) weighted by some measure of abundance such as number of individuals or biomass. However, it is common for conservation biologists to speak of species diversity even when they are actually referring to species richness (Harrison et al., 2004). This concept does not lend itself to explicit illustration in the narrative genre, but any field guide plate including information of frequency of occurrence of a bird species in a given area (e.g., common, rare, endangered, critically endangered) would allow a teacher to introduce this topic as the exact meaning of these descriptive terms is explored. Three of the field guides sampled (National Geographic, 2002; Peterson, 1984; Sibley, 2000) consistently included a description of frequency of occurrence.

## Succession and Recovery

Succession involves the changes that occur in ecological communities over time. Specifically, the presence of specific species may provide an environment that is conducive to the influx of other species (Coweeta Long Term Ecological Research, 2002). Recovery implies the process of the return of the community to ecological integrity following a disturbance. Issues of community recovery are implied by a number of the narrative paintings, and may emerge in the classroom as the ecology of the particular species is discussed. For example, populations of the Quetzal and Forest Owlet are affected by slow community recovery following clearing of forests, and agriculturally motivated fire regimes disturb the habitat of other species such as the Spotted Bowerbird, Carpenterian Grasswren, and Anna's Hummingbird. The natural succession of the community inherent in decaying trees affects the success of bird species such as the Brown Creeper and Ivory-billed Woodpecker. Within the plates and narrative paintings, any species

dependent upon benthic invertebrates (e.g., the Ardeidae) are ultimately affected by climatic and human imposed disturbances to wetlands. Within the field guide plates, illustrations of exotic/introduced species (plates of pigeons and doves, and the waterfowl plates) represent a biotic disturbance that affects the structure of a community.

### Life-History Strategies, Population Ecology, and Predator-Prey Dynamics

Birds occupy many positions along the continuum of reproductive strategies (life-history strategies) - described by Robert McArthur in theoretical terms represented by the symbols  $r$  and  $K$  - with resulting implications for their population ecology. Topics that might potentially emerge in the classroom from this sample of narrative paintings with respect to life-history strategies and population ecology are: egg size vs. clutch size; energetic investment in egg laying, nesting, and parental care; asynchronous hatching, and slow reproduction rates of large predators. These topics may be made explicit by paintings such as Bateman's *The Return – Bald Eagle*, Jonsson's *Coastal Meadow Oystercatchers*, O'Neill's *Black-throated Blue Warbler* or implied by field guide plates that detail the varying annual plumages of birds that take some years to reach sexual maturity (Sibley's illustrations of the Laridae are exemplary).

Almost any image of an engaging bird poses questions about the species nesting habits, and prompting from a teacher can bring some of the more unusual reproductive habits to the attention of the student. Reproduction also frequently segues into issues of conservation. For example, ground-nesting birds have frequently become extinct or endangered (Great Auk, Hawaiian Spotted Rail; certain species of terns) due to egg predation, frequently by humans. The question of predator-prey population dynamics is an aspect of population ecology that is provoked easily by many of the narrative portraits of birds of prey and of scavengers, which are frequently shown hunting in large expanses of landscape (e.g., Liljefors' *Sea Eagle*, Malick's

Prairie Falcon and Martial Eagle, Reinhold's Egyptian Vulture, Thorburn's Gyr Falcon) and also by field guide plates that include prey items with illustrations of this group (Coe; 2001; National Geographic Society, 2002). In general, the topic of predator-prey interactions is accessible through any depiction of a bird dependent upon a prey species, including insectivores such as the Fiscal Shrike, swifts, and martins.

### Limiting Factors

Limiting factors to bird populations are generally food supply (especially for birds of prey, and specialized frugivores (e.g., the Resplendent Quetzal) and nectar-feeders (e.g., the hummingbirds and honeycreepers), space (large wading birds, shorebirds in general), and nest sites, particularly for obligatory cavity nesters (e.g., woodpeckers, swifts and martins, and forest species such as the Forest Owlet. Once again, these factors emerge swiftly from a discussion of many avian species illustrated in the sample of paintings and plates examined here, and overlap with other topics, particularly that of niche. Cavity nesting birds provide a good example of niche partitioning, as many share nesting cavities with other species by means of reproducing at different times of the year. Within the field guide plates, limiting factors to avian populations were identified within the plates of birds of prey, wading birds, waterfowl, woodpeckers, and hummingbirds. In general, the limiting factors to the population of any species may be identified by consideration of the elements comprising the niche of that organism.

### Niche

The formal definition of the ecological niche (Hutchinson, 1957) employs important environmental features such as temperature, pH, nutrient availability, food types and/or sizes, then depicts such features as niche dimensions. There is an identifiable limit for each dimension, such as the minimum and maximum temperatures within which a given species can survive, or

the smallest and largest food items upon which it can feed. The range within which the species can survive represents the fundamental niche for the species, for that niche dimension, and all of these niche dimensions combined represent the overall fundamental niche of the species – the largest ecological niche that the species can occupy.

The fundamental niche is the largest ecological niche that an organism or species can occupy. It is based mostly on interactions with the physical environment and is always in the absence of competition. The niche that a species actually occupies given the presence of other species whose fundamental niches overlap, is described as the realized niche. Niches of birds in a given environment clearly overlap in the areas of food and nest sites, and this overlap is often the explanation of why closely related species do not coexist. Narrative paintings showing multiple bird species occupying the same habitat invite the student viewer to describe the niche of each species, and to consider the areas where the different species may be in competition for the same resource(s). Examples of narrative paintings suitable for such an exercise would include Audubon's plate of four Alcid species, Coe's *Western Rock Shorebirds*, Fuertes' *Rails* and *Diurnal Birds of Prey in Flight*, Martinet's House Martin and Common Swift, and Pratt's Hawaiian Honeycreeper plate. Certain paintings where one bird species is depicted preying upon another Fuertes' *Diurnal Birds of Prey in Flight*, Liljefors' *Sea Eagle Chasing Eider Duck*, Malick's *High Prairie*) illustrate cases where birds themselves are an element of another species realized niche. In the case of the field guide plates, the educator might pose the subtle question of whether the different distributions of closely related species with similar ecological requirements are to some extent the result of competitive exclusion. The niches of birds illustrated in the field guide plates are indirectly described by notes on their distribution and nesting and feeding habits, particularly in the Coe (2001) guide.

### Mechanisms and Results of Evolutionary Processes

Finally, the educator may find fertile ground for discussion all-embracing topic of ‘Mechanisms and Results of Evolutionary Processes’ throughout both narrative ornithological paintings and plates from field guides. Almost all field guide plates and many paintings illustrate sexual dimorphism, implying sexual selection, female choice, and the evolution of reproductive behavior, various dimensions of which are explicitly illustrated in Gould’s *Spotted Bowerbird*, O’Neill’s *Black-throated Blue Warbler*, Jonsson’s *Coastal Meadow Oystercatchers*, and Martinet’s painting of the Common Swift and House Martin, *Le Grande Martinet; Le Petit Martinet*.

Other topics and concepts related to evolution that were illustrated throughout the narrative paintings were endemism (e.g., Keulemans’ Hawaiian Spotted Rail and Maui Parrotbill; Pratt’s Hawaiian honeycreepers; Weatherly’s Grasswren and Fairywren); coevolution of birds with plants (Gould’s Quetzal) and humans (Bewick’s *Rook* and Martinet’s House Sparrows), adaptive radiation (O’Neill’s *Galapagos Finches*; Pratt’s *Apapanes and Akepas*) and the evolution of flightlessness following the evolution of flight (Bateman’s Ostriches; Bewick’s Great Auk; Fuertes’ Rails). Additionally, the taxonomic arrangement of the field guide plates encourages consideration of the species concept and topics within population genetics, as rare morphs and hybrids are frequently shown.

### Teaching About the Nature and History of Science: Potential Contributions of Ornithological Images

Recent reforms in science education target the importance of student understanding of processes and nature of science (Bell et al., 2003), as a key component in attainment of a scientifically literate citizenry. The term ‘nature of science’ typically refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to



scientific knowledge and its development (Bell and Lederman, 1992). Although the specific definition and meaning for the nature of science continues to be debated among science educators, historians, and philosophers (Lederman et al., 2002), one aspect that is generally uncontested is that scientific knowledge is partly the product of human inference, imagination and creativity, and is socially and culturally embedded: “Science as a human enterprise is practiced in the context of a larger culture and its practitioners are products of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion” (Lederman et al., 2002, p.501). A review of these factors necessarily incorporates a historical perspective, as scientific knowledge is placed in a human context across different centuries and geographic regions. Thus the history of science is incorporated within the broader notion of nature of science for the purposes of this analysis.

Certain themes and factors in the development of ornithological illustration are also important within the history of science in general, and the history of ornithology in particular. The most influential of these have been the needs of the scientific establishment at particular points in given countries, the economic and political status of nations, developments in techniques and technologies, the availability of patronage for scientists, the existence of formal and informal communities for the dissemination of information and the availability of mentors for scientists, and the social role accorded to science and the markets thus developed.

Finally, scientific knowledge gains are made to little purpose unless that knowledge is disseminated to a wider community. Consideration of ornithological imagery as a form of scientific communication, intended for specific audiences, may act as a springboard from which

students may ponder wider questions of the communication of knowledge. The development of knowledge in natural history (the precursor of modern ecology) has been visually recorded by natural history illustrators for centuries, thus the lives and products of bird artists provide exemplary material with which to illustrate the history of science and the factors that shaped and influenced this. The AAAS *Benchmarks for Scientific Literacy* (AAAS, 1993), while suggesting that hands-on participation in science projects is the optimal mode of inculcating scientific understanding in students, also considers the life-stories of scientists useful.

The final section of the rubric in Appendix D enquired if and how the paintings and plates conveyed certain aspects of the nature and history of science recommended by the National Research Council (NRC, 1996) and the American Association for the Advancement of Science (AAAS, 1993). Relevant results are discussed in detail in the text below. Answers from the rubric questions were found to overlap and interconnect considerably between portions and did not lend themselves to meaningful quantification, thus the relevant results have been combined and listed under the particular aspects of the nature of science that the images and life stories of the artists were considered to illuminate.

#### Examining Factors in the History of Science With Ornithological Imagery

The painters of certain of the ornithological narratives nicely illustrate some aspects of how the needs of the scientific establishment at particular points in given countries shaped the history of ornithology. For example, dissent over the publication of Linnaeus' *Systema Natura* in the 18<sup>th</sup> century motivated the production of volumes of work by Brisson, Buffon, Bonnaterre, and Levaillant, which in turn provided work for bird illustrators such as Martinet and Reinhold (Zaherek & Overstreet, 2001)

Historically, the emphasis in ornithology has also shifted back and forth between the taxonomic ('bird as specimen') to the ecological ('bird in environment'). Catesby's *Heron, eft, cockroach* is essentially a set of visual notes on the feeding behavior of the Great Blue Heron, reflecting a move toward a more ecologically centered ornithology that first emerged toward the end of the 17<sup>th</sup> century, encouraged by sponsorship from the Royal Society of London. Meanwhile, ornithology as a predominantly taxonomic science flourished under other patrons such as the Emperor Napoleon and the Dutch East Indies Company, who were more concerned with the collecting of exotic specimens (Reinhold's work is exemplary). By the late nineteenth and early twentieth century, inclusion of habitat elements to indicate the ecology of the bird was standard, even by painters doing technical work for museums and scientific societies, as demonstrated by the works of Gould and Keulemans. In the lay community, the bird-oriented collectors of narrative works have leaned toward purchase of works by environmental painters of ornithological subjects such as Thorburn and Liljefors, and more recently Jonsson and Bateman. Despite the overall shift toward an ecologically informed discipline, ornithologists have always retained a concern with visual taxonomic descriptions of new or rare species, illustrated within this sample by Eckelberry's *White-eared Puffbird*, Lane's *Scarlet-banded Barbets*, and O'Neill's *Galapagos Finches*.

More recent illustrators of field guides –e.g., Coe, Fuertes Sibley, Peterson, Pratt, and O'Neill exemplify how a largely non-professional public has created a demand for taxonomically accurate ornithology in the last century with an interest in birds. The field guide plates illustrate the recent explosion in non-academic interest in ornithology in the United States as bird-watching and related activities have achieved public popularity. A similar – though numerically smaller – phenomenon has occurred in Great Britain. The popular interest in birds in Great

Britain has its roots in the early 20<sup>th</sup> century depictions of regional bird fauna by popular artists such as Archibald Thorburn and George Lodge, where the birds placed within landscapes appealed to the persistent British ideal of the leisured country life. Amateur ornithology grew out of this symbolism and became a popular pursuit, creating a market for writing about, and images of, bird subjects (Pasquier & Farrand, 1991)

The political and economic status of nations has also influenced the history of science and ornithology has typically flourished in periods of expansion and exploration. The French enlightenment produced an upsurge of interest in taxonomy, classification, and discovery of new and exotic species in the 18<sup>th</sup> century, reflected within this sample by the works of Martinet and Reinhold (Farber 1997; Pasquier & Farrand, 1991; Stresemann, 1975).

In the 19<sup>th</sup> century, London replaced France as the center of ornithological activity. Following the defeat of Napoleon and the subsequent rise to power of the British Empire, science prospered in England. The collections of the Zoological Society of London and the British Museum expanded enormously; scientific societies and private individuals financed scientific expeditions, and the number of scientific publications (e.g., the *Ibis* in ornithology) grew correspondingly. The interest in discovering new species and documenting new species provided much employment for knowledgeable bird artists. In this sample, the works of John Gould and John Gerard Keulemans are classic examples representative of this period (Farber 1997; Pasquier & Farrand, 1991; Stresemann, 1975).

The United States became a superpower in the 20<sup>th</sup> century; scientific activity flourished accordingly, and continues to do so until the present day. From the late 19<sup>th</sup> century onward, agencies within the United States have been the primary sponsors of ornithological expeditions. Within the sample of ornithological narrative images, Louis Agassiz Fuertes represents one

artist-ornithologist whom the American Museum of Natural History sent on many foreign and domestic scientific expeditions, including trips to Jamaica, Colombia and other parts of South America, Ethiopia (then known as Abyssinia), Magdelene Islands, and Alaska in the early 20<sup>th</sup> century (Chapman, 1908; Drahos, 1968). Contemporary American bird painters such as Dan Lane, Don Malick, John O'Neill, and Doug Pratt have continued to represent burgeoning American interests in ornithology in expeditions to Central and South America, Africa, and the South Pacific, and John O'Neill and Dan Lane have achieved notoriety in the ornithological community for their discovery of new species upon these expeditions. Sophie Webb continues to participate in expeditions to the Arctic and Antarctic under the sponsorship of the National Oceanographic and Atmospheric Administration (NOAA).

Advances in science have frequently followed in the wake of new techniques and technologies, such as the impact of light and electron microscopy, and X-ray analysis upon many fields of biology and physics. The ultimate aim of ornithological illustration is the dissemination of scientific knowledge of birds, and thus the advancement of ornithological knowledge is linked to improvements in technologies of visual representation. Within the sample of narrative ornithological paintings, the works of Thomas Bewick provide an example of how an improved technique advanced visual representation of knowledge of birds. Bewick briefly revived the technique of wood-engraving at the end of the 18<sup>th</sup> century (Bain, 1981), and then pioneered the technique of white line engraving, which allowed for much more detail and textural effects in illustration. Thus Bewick's two-volume *History of British Birds* allowed for much more of the subtlety of the artist's observations to be transmitted to the viewer than was possible in previous engraved works, and most paintings.

Catesby's fine watercolors and etchings have been criticized for colors that seem less than natural, an explanation for which is that the range of colors available to him at that time were not adequate to those of nature (Farber, 1997; Pasquier & Farrand, 1991). Later ornithological artists were able to represent the colors of bird plumage and relevant habitat elements with greater accuracy. Such representations have also been subject to alteration during the printing process. Audubon was well aware that the technological shortcomings of the printing process could dilute the quality of his work, and made sure he was on hand in London to oversee the translation of his meticulously rendered watercolors into aquatints (Ford, 1993; Fries, 1973); an indication of the responsibility incumbent upon a scientist for the accurate dissemination of his ideas.

Probably the most significant technical advance that contributed to the dissemination of visually rendered ornithological knowledge was the use of photography in the early twentieth to reproduce original images (Pasquier & Farrand, 1991). Ornithological images could then be available to a wide audience, rather than a few subscribers or individuals having access to select libraries. The field guide plates are exemplary in this respect; communicating ornithological knowledge to a much larger audience than had been possible in previous centuries.

Funding science is a major preoccupation of many practitioners today; a facet of scientific life shared with many of their predecessors (Janovy, 1996). Historically, many naturalists have been dependent on the patronage of private individuals to support their explorations. Of the artists represented in the sample of narrative paintings, Audubon, Bewick, Catesby, and Gould were among those who financed their work by disseminating their artwork by private subscriptions. Other sources of financial support were scientific societies and

institutions, and such sources have tended to increase in importance throughout the history of science, as such institutions have become both more numerous and more influential.

The observations of Mark Catesby (1682-1749) - the first major figure in American ornithology - for his great treatise *The Natural History of Carolina, Florida and the Bahaman Islands* (1731-43) were ultimately made possible by the support of the Royal Society of London (Zaherek & Overstreet, 1999). Catesby's first trip to the colonies was at his own expense, but the collections of seeds and botanical specimens with which he returned to England initially attracted the interest of wealthy individual patrons, and finally earned him institutional support. A century later, itinerant French ornithologist Francois Levaillant (1753-1824) obtained patronage from wealthy specimen collectors in Paris and Holland, enabling his ornithological explorations in Africa that were visually documented by J. Lebrecht Reinhold (Brenthurst Press, 2004).

John Gerard Keulemans - represented within the sample of narrative ornithological images, as are Catesby and Reinhold - was the most sought-after bird artist in Europe from 1870 to 1910, esteemed for his high standard of scientific accuracy. Keulemans possessed the ability to create striking and accurate representations of birds from specimens, due to his immense knowledge of both the principles and vagaries of bird anatomy (Keulemans & Caldeway, 1982; Pasquier & Farrand, 1991). In his early twenties, the Dutch-born Keulemans was mentored by Dr. Herman Schlegel, a renowned zoologist and director of the natural history museum in Leiden, who brought him on an ornithological expedition to Africa and then hired him onto the museum staff and encouraged his artistic development. Soon Keulemans attracted his own commissions for natural history illustrations, mainly from England, where many zoological specimens arrived from a variety of scientific expeditions throughout the 19<sup>th</sup> century. In

addition to individual patrons, Keulemans received substantial support throughout the remainder of his career from the British Museum and the Zoological Society of London.

Keulemans' story is an example of the transition to the modern situation where scientists obtain financial support for their endeavors from institutional sources, such as universities, museums, research institutes and scientific societies with the ability to make funding available via grants. In the 20<sup>th</sup> century ornithology prospered as a professional discipline and a number of the 20<sup>th</sup> century artists have or have had institutional ties and obtain support for their ornithological work through this route.

A number of such artists supported in this way are included in this study, including Coe, Eckelberry, Malick, McQueen, Peterson, and Webb. Coe and McQueen have associations with the Cornell Laboratory of Ornithology, and Eckelberry and Peterson received support from the National Audubon Society. Louis Agassiz Fuertes participated in many expeditions under the auspices of the American Museum of Natural History, an institution that has also aided the work of Sophie Webb. Webb has also been employed on NOAA cruises to the Arctic and Antarctic, and much of Don Malick's bird knowledge was acquired with the assistance of the Denver Museum of Natural History and the National Museum in Botswana.

One final aspect of the nature of scientific practice that is amply illustrated historically by ornithological illustrators, is the existence of formal and informal communities of practice that serve to disseminate information between practitioners and also provide mentoring for junior scientists. The traditional myth of the scientist as a solitary genius in an intellectual ivory tower is dispelled by modern reality, in which practitioners are socially and intellectually supported in their work and thinking by others in their discipline. A review of the biographies of ornithological illustrators shows that this situation is both a contemporary phenomenon and one



that has also existed in one form or another for centuries. Before ornithology became a recognized professional discipline, amateur ornithologists formed informal associations, which served the purposes of mentoring, peer review, and the provision of stimulation for their activities by the exchange of knowledge and ideas.

Collaborations between ornithologists illustrated by the producers of images analyzed in this study are described below in approximately chronological order. Profound influences of one naturalist-artist on another are included, as this may be considered an impersonal variant of the master- pupil relationship.

Audubon was heavily influenced by the work of his predecessor Mark Catesby, especially with respect to the latter naturalists insistence upon inclusion of botanical settings for his bird portraits. Audubon was also directly mentored by pioneer American naturalist William Bartram, and later exchanged ornithological knowledge with the “Father of American Ornithology” Alexander Wilson, and others including Thomas Bewick, Prideaux John Selby, and William Swainson.

Louis Agassiz Fuertes fulfilled the role of historical mentor to other of the artists of narrative paintings included in the sample. Eckelberry, Lane, McQueen, Malick, Peterson, O’Neill, and Pratt all mention seeing Fuertes’ work as young and aspiring ornithologists and deriving inspiration and direction from Fuertes’ mode of observation. Malick and O’Neill received indirect tutelage from Fuertes as both were instructed by University of Oklahoma zoology professor George Sutton, who himself had been a pupil of Fuertes. O’Neill later extended this heritage by serving as mentor to graduate students in ornithology at the Museum of Natural Science at Louisiana State University, including H. Douglas Pratt and Dan Lane.

John Gould, in his role as provisioner of ornithological imagery to Great Britain for fifty years, was extremely conscious of the value of collaboration. Gould toured museums and zoos to learn from experts when he was producing *Birds of Europe*, and employed professional ornithologists – in particular Vigors and John Gilbert of the London Zoological Society – to travel with him in Europe and Australia until his scientific skills were sufficiently honed for him to write his own texts and direct the portrayal of birds with accuracy (Lambourne, 1987). Gould's expertise was clear when he identified 13 new species of finch from the Galapagos Islands based on small differences in bill morphology, and thus influenced his contemporary Charles Darwin's theory of natural selection (Australian Museum, 2004). He went on to contribute to the ornithological network of the time by providing employment for naturalist – artist – lithographers Conrad Richter and William Hart, and was instrumental in developing the British career in ornithological art of German painter-naturalist Joseph Wolf, who in Europe had been the protégé of zoologist Herman Schlegel, director of the natural history museum in Leiden. One fortunate result of Gould's extensive use of collaboration was that after his death in 1881, a curator at the British Museum was able to complete the text of his last book, *The Birds of New Guinea*. Commentators Pasquier and Farrand (1991) judge that Gould's greatest gift to 19<sup>th</sup> century ornithology was the establishment of a cooperative community, in which the value of artistic products and ornithological knowledge exceeded the sum of individual contributions.

Collaboration among ornithologists remains strong today, and was exemplified in the 20<sup>th</sup> century by the community of ornithologists and artists committed to describing and depicting the birds of South America based in and around the Museum of Natural Science at Louisiana State University. Within the sample of ornithologists analyzed here, John O'Neill, renowned academic ornithologist in addition to his almost legendary status as a contemporary illustrator,

and former director and research associate of the museum, has been important as mentor and teacher of other artists and ornithologists, including H. Douglas Pratt and Dan Lane. Larry McQueen and many other contemporary painters also have strong ties to the ornithological research community at the museum.

### The Practice of Science: The Critical Importance of Observation and Reflection

Progressing from the consideration of the factors that affect scientific practice, to the process of science (i.e., how science is actually practiced by its initiates), an additional important aspect of the nature of science in education is the notion that science and scientific progress are ultimately rooted in observation, and that there is a lack of a universal recipe for doing science, the paradigmatic scientific method recited by most high school and college students notwithstanding (Lederman et al., 2002). This is especially relevant to ecology, a field of endeavor that while incorporating experimentation in some areas, is rooted in descriptive and interpretive practices. Thus the realization of field observations - and the reflective interpretation of such observations - as the bedrock of ecologically oriented science practices illuminates descriptive and interpretive modes of science that are ultimately critical to experimentation. That students should expand their view of the nature of progress in scientific knowledge beyond that of incremental advances resulting from the repeated applications of the experimental scientific method is emphasized in 'The Nature of Science' portion of the AAAS *Benchmarks* (AAAS, 1993, Chapter 1), which are primarily concerned with the idea that scientific knowledge claims are based upon empirical data that supports abstractions based upon initial observations, with particular emphasis upon the importance of reflecting and re-reflecting upon observations.

Research has consistently shown that student understanding of the nature of science is not developed through participation in school science projects, despite the recommendations of the

NRC *Standards* to pursue inquiry-based science education. Bell et al (2003) found that an apprenticeship program in which students experienced real data collection and interpretation issues, and discourse with working scientists did not change students' tenaciously held beliefs in a linear scientific method, and as the scientific enterprise as a progression toward absolute truth, a situation which is arrived at when sufficient data has been gathered to 'prove' a theory. An understanding of the role of scientific creativity in interpretation of observations and data appeared lacking in the students before and after their apprenticeships, as was the potential value of anomalies in data. A proffered explanation for the failure of hands-on scientific experience or inquiry activity to inculcate an understanding of the nature of science is that such experiences and activity is not necessarily accompanied by reflection: "Dewey never said that we learn by doing. He said we learn by doing and by thinking about what we are doing (Rowe, 1978). By paraphrasing this as "we learn by reflecting upon what we see", and given the failure of hands-on experiences to produce understanding of the role of observation in science, it follows that a student might then learn more about the role of observation in ornithology by reflecting upon an image of a bird than upon a field trip to see birds. It is hypothesized in this study that ornithological illustrations may be fruitfully presented to students as exemplars and records of detailed observations that have been subject to such reflections by their producers, and also by implication, that these producers embody the scientific values and attitudes of honesty and curiosity espoused by the AAAS *Benchmarks* in 'Habits of Mind' (AAAS, 1993, Chapter 12).

#### Teaching About the Role of Observation in Science

Since ornithological illustrations are generally the result of multiple, sustained, and often strategically obtained field observations on the part of the artist, followed by acts of interpretation and critical judgment, all accurate ornithological paintings have the potential to

direct the viewer's attention to the role of observation and reflection in ecology. If one takes the position that the completed illustration is analogous to a scientific report, the following questions arise with respect to the scientific methodology necessary to produce the image:

1. Did the information presented in the image necessarily need to come from a field viewing, or could it reliably have been obtained from a specimen?
2. Where and how did the illustrator position himself /herself to observe the bird(s)?
3. From how many aspects did the observation need to be made? At different times of day? At different seasons? In different locations?
4. How many observations of the bird(s) would have to be made before the artist could be sure he was seeing a typical specimen, rather than some oddity or variant?
5. How much prior knowledge of the bird(s) was necessary to interpret these observations in order to make a meaningful scientific report? Would a photograph of the bird (i.e., lacking the elements of reflection and observation by the producer) have accomplished the same objective?
6. What information is lacking in the illustration, and/or what questions are raised? What types of further observations or investigations would need to be made in order to obtain this information?

Subjecting a variety of ornithological images to analysis by such probing should make clear to a student that engaged seeing is a very different matter from looking, that forethought and reflection are critical to making useful observations, and how properly conceived and interpreted observations may serve as data.

#### Teaching About the Scientific Disposition, or "Habits of Mind"

Viewers can likewise be led to consider the disposition, or necessary "Habits of Mind" of scientists by considering the making of an ornithological image. The overarching question to be

posed to the student here is: What are the individual qualities necessary to observe and report ornithological data in this manner?

The attribute of curiosity should soon emerge from consideration of this question, followed by those of persistence in the face of misleading views and anomalies, and honesty in recording and interpreting visual data, and a facility for critical response. The question set previously suggested to explore aspects of observation should also illuminate the need for sufficient prior knowledge of the observed material, in order for the artist to make informed judgments about observations, based on what is known or unknown about the birds – this skill of critical response is much emphasized in the AAAS *Benchmarks*. Finally, examining images in this manner has the potential to convey an impression of the drive of naturalists to develop a deep and integrated understanding of observed phenomena, and to develop an appreciation for the ideas and data contained within scientific images, and the communication skills that are essential to their production.

#### Science as a ‘Human Adventure’

This study also hypothesizes that exposure to the lives of illustrators and their artistic products may contribute to a more positive perception of science, a factor that is key in student’s interest in, and persistence in, science courses (Cavallo & Laubach, 2001). This postulated response to the life stories of artist-naturalists serves the insistence of the AAAS *Benchmarks* insist that science should be communicated to the student as an adventure in which all can participate, rather than as a specialized endeavor requiring professional status. Only four individuals – Dan Lane, John O’Neill, Bill Strausberger and H. Douglas Pratt – among the artists of the narrative paintings and the field guide plates – are academically trained ornithologists. Many of the contemporary painters do have bachelor’s degrees in other subjects, and McQueen,

Barnes, Webb and Coe have some generalized academic training in biology. However, the vast majority of these illustrators, many of whom have made substantial contributions to ornithological knowledge by their field observations, have retained true amateur status. The biographies of such contributors exemplify for the student how passion for the subject matter, and the drive and curiosity thus engendered is the true fuel of the scientist, and also indicate how an individual may become truly accomplished in an ecological area of interest by utilizing informal resources such as accessible local experts, clubs, and libraries.

### Summary

The nature and history of science is considered an integral part of science education by recognized authorities such as the National Science Teachers Association, the National Research Council and the American Association for the Advancement of Science (American Association for the Advancement of Science; California Regional Environmental Education Community, 2000; National Research Council, 1996). These topics are also among the most problematic in terms of instruction, as inquiry activities so successful in reinforcing conceptual material and stimulating interest in science have not been found to produce broad and integrated notions of the nature and history of the discipline in students.

Within the area of ecology education, ornithological imagery has the potential to stimulate reflection on historical aspects of science by study of the lives of the illustrators, and the dispositions and practices of ecologists via analysis of the processes that go into the making of such images. The lives of the illustrators demonstrate many of the factors that affected ecology – and its disciplinary predecessor, natural history - through history. Biographies of contemporary illustrators may prove to be both enlightening and inspiring to students. These are available in many cases on the internet, and the human interest dimension that they provide may

serve as a hook to stimulate interest in science, and to demonstrate that ecological expertise is available to interested individuals outside of a purely academic training.

If an ornithological image is considered analogous to a scientific report, an analysis of the field observations and thought necessary to the making of a particular image, has much to teach about the roles of observation and reflection in ecological areas of science. Extending this analysis to a consideration of the personal qualities necessary to carry out such work exemplifies some of the dispositions of scientists, with respect to curiosity, honesty, a drive to seek explanations, the ability to make careful and critical judgments, and the possession of clear communication skills.



CHAPTER 6: CONCLUSIONS.  
WHAT IMPLICATIONS DO THE LIFE HISTORIES, PRACTICES, AND PRODUCTS OF  
ORNITHOLOGICAL ARTISTS HAVE FOR EDUCATION WITHIN THE AREA OF  
ECOLOGY AT THE HIGH SCHOOL  
AND COLLEGE LEVEL?

In this chapter, the results of the four subquestions that were presented in Chapter Four and Chapter Five are summarized and combined into a general picture of how this information might be useful to ecological educators. There are two general areas of meaning: how the information informs the education of potential ecologists as a whole, and also how this information may be useful within a formal instructional setting. The life stories of the illustrators tend to inform the field in a wider sense, whereas the products of the illustrator, i.e., the images of birds, have implications for the classroom.

Implications of the Study for the Education and Development of Prospective Ecologists.

One of the broadest and most general conclusions of this study is that expert and committed naturalists are drawn from a wide variety of personality types, gain their eventual expert status via a number of pathways and that ecological expertise is found in other professions than that of academia. With respect to the variety of types of personality drawn to this area, I cite the contrast between the idealism of O'Neill, Strausberger, and Coe (who appear concerned with the deeper implications of their work beyond the transmission of technical information); the energy and bubbling enthusiasm of Lane and Barnes; Pratt's determined pragmatism; Webb's affect of gentle wonder and deep quiet love of organisms, and the glowing spirituality of McQueen, masked as it is behind a natural rectitude. Thus despite the large body of work attempting to assign distinct characteristics of personality to scientists that was conducted through the 1950's-1980's; this case study suggests that the field of natural history attracts a wide variety of personalities.

The triggering factor in the development of expertise in field ornithology (a subset of the field of ecology), appears to be a fascination with a particular organism or group of organisms, often accompanied by a bent toward a particular type of environment. This interest appears to be innate insofar as it appears in early childhood and is independent of genetics or environment, and is possibly a manifestation of the naturalist intelligence (Gardner, 1999) or an intense degree of the biophilia posited by Wilson (Wilson, 1984). The development of skills in the field, outside of those provided in a formal educational setting, is greatly assisted by the individual's access to materials, individuals, communities of practice, and institutions. Access to these resources also appears to provide sustenance for the individual worldview, suggested by Janovy (1985/1996) that the love of organism(s) provides a legitimate basis for a life in biology, and that such values, once legitimized, can assert themselves and provide an unshakeable direction for life choices.

My explicit assumption here is that the ornithological artists represent a subset of expert ecologists, since the practice of field ornithology that has been shown necessary to the production of these images is largely rooted in ecological expertise. Also, although a number of participants in the study identified themselves as artists, it became clear that it was love of the organism and associated habitats that largely drove the interest in art, thus these individuals, as a subset of expert naturalists, may also be regarded as exemplars of expert ecologists. The label of 'expert ecologist' does not necessarily imply that such an individual is necessarily destined for academia or research, for as the life stories of these ornithological illustrators demonstrate, such expertise and passion has been carried into careers including school teaching, independent practice as gallery artists, working in the tourist industry, and production of children's science books, in addition to more conventional scientific careers. To reiterate, this was only a small

case study and many more life-directions/professional practices might be built upon such expertise in ecology than emerged from the results here.

The study suggests that an interest in organisms and ecology manifests early in life, and develops independently of formal education. The availability of resources such as books, videos, museums, experienced adults, and active associations such as bird clubs and Audubon groups is important in facilitating the development of the early interest and the growth of the knowledge base in the incipient naturalist. In the high school years, the opportunities for travel and development of a more specialized knowledge may be facilitated by the assistance of school teachers who recognize the intensity of the student's interest and direct the student toward resources and individuals who can assist the continued growth of the student's expertise, and support his or her values and worldview.

The college years are ones in which the early childhood passion and adolescent enthusiasm are subject to more scrutiny by the individual, and one in which competing and more conventional careers beckon as a 'safer' alternative. This is a time at which the role of academic mentorship assumes a greater importance, and provision of extra-curricular opportunities to develop expertise remains critical, as does introduction to a 'community of practice' to provide support for the developing worldview of the organism and environment as being of central importance in the lives of dedicated biologists, and also to provide a network of colleagues and a vision of potential opportunities for the future. The interviews suggested that exposure to research groups, participation in professional activities and fieldwork, on a formal or informal basis, serves to anchor the incipient ecologists vision of ecology as a life-course as a workable alternative, and helps refine ideas as to his or her next move after graduation.

Thus the findings of the first part of this exploratory study imply that a potential for the naturalist intelligence may be recognized in students of all personalities and backgrounds, and frequently first manifests itself in an expressed love of a particular organism or group of organisms, often accompanied by a preference for a distinct ecological environment. Assisting students of all ages to discover role models and experts within the area of ecology may be key in providing inspiration to develop the naturalist dimension of intelligence. Introducing students to resources outside the classroom, wherein they can find opportunities to pursue their interests independently, and also find expert mentors and future colleagues, may be more effective than within-school programming in supporting the development of their naturalist skills. Programs with the context of formal education that encourage students to discover and identify such resources for themselves may also be useful in targeting students that have not individually come to the attention of an interested educator (inside or outside the school system), and might be offered in the form of classroom activities, in school libraries, or by school biology clubs.

In larger terms, identification and development of the naturalist intelligence or the biophilic orientation, where this potential is present in students, should be of concern to the ecology educator for the following reasons:

1. Encouragement of this potential launches the student on a lifelong journey that engages the spirit as well as the intellect (Wilson, 1984; Leopold, 1966; Eisley, 1964).
2. The inherent aesthetic rewards of the study of nature provide a comfortable bridge between the cultures of art and science, as the study of organisms inevitably leads to discovery of the rich source of imagery from contemporary and historical sources.
3. The ability to observe nature, and to understand and interpret those observations, is a sound basis for the development of a conservation ethic (Wilson, 1984)

### Implications of the Study for Ecology Education in a Classroom Setting.

The second part of this study addressed the uses of ornithological images in ecological education. I suggest that those in whom the naturalist orientation is dominant may well discover such imagery independently, but the large proportion of the student population who do not possess such a drive might well have their awareness and understanding of ecological issues and concepts awakened and deepened by use of such imagery in a classroom setting. The potential instructional uses of ornithological images that are suggested by the study are as follows:

1. Using ornithological images as an aesthetic hook to increase interest in the subject matter of ecology.
2. Use of ornithological images to demonstrate, reinforce, and explore particular concepts and topics in ecology within the high school and college classroom.
3. Use of ornithological images and the life-stories of ornithological illustrators to convey aspects of the nature and history of science.

### Using Ornithological Images as an Aesthetic Hook to Increase Interest in the Subject Matter of Ecology.

As stated in the rationale for this study, birds have a particular fascination for many people, provoking an acute identification with the natural world (Kastner, 1988). The attraction of this group of organisms has its roots in a number of factors, including the sensory appeal of their appearance, their wide availability to the casual observer, and the appeal of the ideal of personal freedom symbolized by the power of flight. Statements from a number of the ornithological artists interviewed confirmed this assertion; Jim Coe believing it is the relative accessibility of birds and the fact that bird watching can develop into an ongoing interest without the acquisition of specialized knowledge that is necessary for other areas of natural history such

as the identification of plants, insects and fossils, and Larry McQueen holding that many bird lovers are attracted by the illusion of personal freedom conferred by the ability to fly. Eustace Barnes added the suggestion that bird watching offers gratification for an innate hunting instinct in children, and also that birding offers a respite to many educationally and socially disadvantaged person from otherwise constrained lives. Whatever the specific motivation may be, it would appear that birds are an irresistible hook into the wider area of ecology for many.

This study posits that images of the birds when field experiences with the actual organisms are unavailable can function as much the same aesthetic hook into ecology. This is hardly an original idea: John Janovy (1985/1996) devotes much of a chapter in his book of essays on the nature of biology and biologists to discussing the greater biological awareness that attractive images of organisms can generate in the viewer. Additionally, Harry Robin has posited six functions of science - observation; induction; methodology; self-illustration of phenomena; classification, and conceptualization - that may be served by appropriate images (Robin, 1992). In this study, the sample of narrative ornithological paintings and the sample of field guide plates surveyed were found to conform to a high degree to Tufte's (1983; 1990; 1997) criteria for excellence in scientific graphics, particularly with respect to qualitative and quantitative accuracy, and in the number of relational possibilities offered by the images. As listed in Table 5.7, many narratives also offered an easily discernable visual biological or ecological 'story line', such as community ecology, reproductive ecology, limiting factors, extinction and evolution.

Once again, the comments of the bird artists support this claim that attractive images of birds are of wider ecological import: Strausberger points out that good bird paintings amount to science presented with an interesting visual story line, O'Neill reflects that his narrative paintings

reach and interest a wider public than do his technical works, and that the key to this is simply increased enjoyment of the images, and Barnes believes that public interest in conservation of key habitat often begins with compelling bird paintings in books of the coffee-table genre. Dan Lane hypothesizes that when an artist is able to capture the gestalt of a bird, the viewer shares the excitement of this discovery of the bird's 'personality' and goes on to take note of other features of the painting that reflect the artist's understanding and knowledge of the organism and habitat. Biology teachers at the high school and college have informed Jim Coe that the narrative paintings he placed at the front of his guide have served to stimulate interest in the technical images presented in the more formal part of the text, and Sophie Webb is aware (again via teacher reports) that her illustrated children's books have produced a genre of 'Sophie Groupies' in elementary schools, all of whom declare an intention to become field biologists and conserve the coastal environment for seabirds

The particular concepts listed by the artists in the sample interviewed for this study, as they discussed their own work, included endemism, extinction, brood parasitism, competition, foraging strategy, predator-prey interactions, aerodynamics of flight, sexual selection and variation, ecology and conservation of wetland, prairie, and cloud forest habitats, and the regional variations in species that have implications for population genetics and the mechanisms of evolution. Many more concepts and topics in ecology found in the analysis of the selected samples of paintings and plates are listed in tables 5.23 and 5.27.

Thus I suggest here that an attractive image of birds, particularly one containing an exotic species, a dramatic interaction such as a moment of predation, or an exotic environment, has multiple uses in the classroom to introduce or demonstrate a number of ecological concepts. Most students will pay attention to interesting and unusual images, and as Tufte (Tufte,1983)

holds, the information may be transmitted faster and also be more memorable than verbal explanations or representations.

Use of ornithological images to demonstrate, reinforce, and explore particular concepts and topics in ecology within the high school and college classroom.

Twenty ecological concepts (Figure 6.1) were extracted from those emphasized as important in teaching ecology at the high school level by the American Association for the Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996), and at the college level by the British Ecological Society (Cherrett, 1989). All concepts were found to be either explicitly illustrated or implied within the combined sample of narrative paintings and plates. There is no particular pattern of concepts better illustrated by either genre, with the exception that the concept of species diversity did not lend itself to illustration within the narrative genre, and that energy flow was not illustrated by the field plates.

**Figure 6.1. Twenty ecological concepts designated as important in ecology education at the high school and college level by the American Association for the Advancement of Science, the National Research Council, and the British Ecological Society.**

Ecological Concept	
1.	Carrying Capacity
2.	Community
3.	Competition
4.	Conservation of Resources
5.	Ecological Adaptation
6.	Ecosystem
7.	Ecosystem Fragility
8.	Energy Flow
9.	Environmental Heterogeneity
10.	Food Chains/Webs
11.	Human Impact
12.	Interdependencies Between Species
13.	Life History Strategies
14.	Limiting Factors
15.	Mechanisms and Results of Evolutionary Processes
16.	Niche
17.	Population Ecology



	<b>Ecological Concept</b>
18.	Predator Prey Interactions
19.	Species Diversity
20.	Succession and Recovery

A number of these topics and concepts are illustrated explicitly, such as ecosystem, community, energy flow, interdependence of birds and plants, and predator-prey interactions, and these are suitable for incorporation into a lecture format, as examples of concepts described by the instructor. Paintings or plates where concepts are implied rather than explicitly illustrated, such as in carrying capacity, limiting factors, ecosystem fragility, and conservation issues, have great potential for use in inquiry based activities in which the student mines the concept following independent research into the species and/or habitat illustrated. This latter use of images is relatively easily implemented with access to the worldwide web, where extensive and accurate information on birds and their habitats is widely available. A further use of such images lies in assessment, where the student can identify the visual representation of concepts previously taught in class.

#### Use of Ornithological Images and the Life Stories of Ornithological Illustrators to Convey Aspects of the Nature and History of Science.

Certain factors in the history of science are illuminated effectively by consideration of the history of ornithological narratives. Discussing – or requiring students to research – ‘the story behind the painting’ invokes many of the factors that have fashioned the progress of ornithology, such as the relative emphasis upon taxonomic or ecological aspects of the science, the influence of the economic status of certain nations throughout history upon the cultural demand for more ornithological knowledge, the effect of technology upon the visual representation of science, and the importance of funding for scientific exploration and the avenues through which funds have

historically been obtained. As discussed in Section III of Chapter 5, some aspects of the sociology of science, particularly the means by which ornithological knowledge has grown through collaborations, and been disseminated among its practitioners through communities of practice is also nicely illustrated by an exploration of the lives of some of the great bird illustrators. Finally, a case study of these biographies by students, including those of contemporary illustrators, may serve to engage students with the notion of ‘science as a human adventure’ (AAAS, 1993), or an endeavor in which individuals with widely varied backgrounds and abilities may participate.

One essential element of scientific methodology that is frequently insufficiently addressed in many science courses is the role of observation and reflection upon observations. Accurate ornithological illustrations possess the potential to direct the viewer’s attention to these processes. If a completed narrative painting or field plate of birds is considered as analogous to a scientific report, much understanding of these essential processes of science might be gained by subjecting the image to an analysis of the nature of the observations that were necessary in its production (see the suggested exercises in Chapter Five, Section III), and emphasize to the student that engaged seeing is much more than mere ‘looking.’

Understanding of the characteristics of scientific thinking is also emphasized by the American Association for the Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996). As John Janovy (1985/1996) wrote concerning an exhibition of George Sutton’s Arctic and Mexican bird paintings that drew “shoulder to shoulder crowds “(p.34), images of organisms in landscapes serve “as a window through which (others) see the working of a scientist’s mind” (p.34). Thus the disposition and characteristics necessary to produce exemplary works of ornithological illustration might be discussed with students, and should

illuminate attributes of curiosity, persistence, honesty in evaluating and recording data, and the necessary skill of critical reflection upon that which is observed (See Chapter Five, Section III). Such an exercise also has potential to transfer to a wider appreciation of the ideas and data contained within other scientific images, and of the importance of visual communication skills in science.

In conclusion, this study suggests the following answers to the primary research question, which asks how ornithological illustration might potentially contribute to ecology education. First, the lives of the illustrators provide a model for the development of expertise in this area of biology. Second, ornithological images appear to function as effective scientific graphics that can be mined to demonstrate, reinforce, and relate many critical ecological concepts, in addition to serving as a valuable resource in conveying the history and nature of science.

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## APPENDIX A: PARTICIPANT CONSENT FORM FOR DISSERTATION STUDY OF ORNITHOLOGICAL ILLUSTRATORS AND ORNITHOLOGICAL ILLUSTRATION

Principal Investigator:  
Vanessa Hunt [vhunt@lsu.edu](mailto:vhunt@lsu.edu)  
225 381-3085

Project Description: This doctoral research study is concerned with describing the lives, beliefs, values and practices of contemporary bird artists. The project is conceived as a multiple case study of a sample of eight artists. Each case will be analyzed and described, then compared and contrasted with the other artists to form a holistic picture of the lives and worldview of these artists. The study also wishes to determine if these artists exhibit evidence of possessing a specialized ‘naturalist intelligence’ as described by Howard Gardner (Gardner, 1999), and to develop a tentative model of the developmental trajectory of this unique ability.

Project Procedures: Participation in this project will involve completion of an audio taped interview, during which participants will be asked about to discuss their educational background, training in ornithology and visual arts, and their work practices and career history. Participants will be invited to share their thoughts upon contemporary cultures of art and science. On completion of the interviews, which are projected to last approximately three hours, the tape will be transcribed and the data analyzed and interpreted.

Interpretations and conclusions will be published as part of a doctoral dissertation study in the Department of Curriculum and Instruction at Louisiana State University. These are expected to incorporate direct quotes from the interviews and participants will be identified by name.

Potential Risk(s): The risk to you is that your identity and your statements during the interview will be disclosed. Additionally, you may disagree with interpretations of your statements. If at any time you have questions about these risks and potential risks, please contact Vanessa Hunt at the address listed above.

Your participation is entirely voluntary and you may decline to answer questions during the interview, and terminate the interview at any time. When the analysis of the transcripts is complete, you will be given the opportunity to review interpretations of the data. If you are uncomfortable with interpretations of your statements, you may withdraw consent for publication of your identity, and request that a pseudonym be substituted.

I have been fully informed of the above-described procedure with its possible benefits and risks, and I give my permission for participation in the study and disclosure of my identity.

---

Participant Signature

APPENDIX B: EVALUATION OF NARRATIVE ORNITHOLOGICAL ARTWORK IN  
ACCORDANCE WITH EDWARD TUFTE'S (1983; 1990; 1997) CRITERIA FOR  
EXCELLENCE IN SCIENTIFIC GRAPHICS

Title/Date of Work:

Artist:

Source:

Major Axioms:

Maximum Use of Data Ink

Estimate the area of the painting devoted to the bird(s), or to portraying relevant ecological information about the bird or birds. Ignore white space, background wash, and sky.

75 – 100 % of total area \_\_\_\_\_

50 – 75% of total area \_\_\_\_\_

Less than 50% of total area of painting \_\_\_\_\_

*Comments:*

Inclusion of Relational Aspects of Phenomena

Does the painting explicitly indicate relationships between the bird(s) and relevant ecological variables, thus encouraging the viewer to infer possible causal relationships?

List relational aspects of the painting: concepts or phenomena that are illustrated or implied.

Principles of Integrity:

a) Is the bird qualitatively correct, with respect to morphology and field marks?

Totally correct: \_\_\_\_\_

Errors are apparent \_\_\_\_\_

Impossible to determine \_\_\_\_\_

Comment (describe perceived shortcomings):

b) Are quantitative aspects of the bird correct?

Totally correct: \_\_\_\_\_

Errors are apparent \_\_\_\_\_

Impossible to determine \_\_\_\_\_

Comment (describe perceived shortcomings):

c) Where relevant, as in mixed species paintings, or when birds are shown against features of their habitat, are visual drifts in scale apparent?

Species are scaled appropriately with respect to each other \_\_\_\_\_

Species are scaled appropriately with respect to background phenomena \_\_\_\_\_

Visual drifts in scale are apparent \_\_\_\_\_

Comments:

d) Content-free decoration apparent in this work: Are any background elements irrelevant to identifying or understanding the bird? Check all that apply.

All background elements have ornithological or ecological relevance \_\_\_\_\_

Some background elements appear irrelevant/merely decorative \_\_\_\_\_

Decorative elements are justified by their contribution as an aesthetic  
hook, or by contributing to the 'jizz' of the species \_\_\_\_\_

Comments:

e) Does the illustration of each species in the plate provide direct information (about the following (check all that apply):

a) Size? \_\_\_\_\_

b) Form? \_\_\_\_\_

c) Morphological adaptations? \_\_\_\_\_

d) Behavior? \_\_\_\_\_

e) Habitat? \_\_\_\_\_

f) Distribution? \_\_\_\_\_

Comments:

f) If a mixed species painting, does the work adhere to the principle of proper context by indicating exactly how the organisms are related, i.e., by taxonomy or by habitat? Is the reasoning for the inclusion of the different species made obvious to the viewer?

The different species are related by (specify relationship): \_\_\_\_\_

The relationship between the species is not obvious \_\_\_\_\_

Not applicable: single species portrayed \_\_\_\_\_

Comments:



g) Overall, does the illustration display data variation while restricting design variation?

Yes – the emphasis of the painting is upon content and data \_\_\_\_\_

No – the painting substantially emphasizes design and decoration  
to an extent that this detracts from the content \_\_\_\_\_

Conveyance of the Multivariate Nature of the Subject Matter,  
and Determination of the Degree of Information Resolution:

a) How is the dimension of time indicated in this work (check all that apply):

Depiction of motion \_\_\_\_\_

Variations in age of birds \_\_\_\_\_

Variations in seasonal plumage \_\_\_\_\_

Life-cycles of plants or birds implied \_\_\_\_\_

Time is not indicated \_\_\_\_\_

Other (specify) \_\_\_\_\_

Comments:

b) Which of the following visual comparisons are invited by the painting? Check all that apply:

Behavioral comparisons \_\_\_\_\_

Ages/ stages of maturity \_\_\_\_\_

Geographic variation within species \_\_\_\_\_

Postural differences \_\_\_\_\_

Gender differences \_\_\_\_\_

Comments:

- c) Is a micro-macro approach to the scene employed, where detail is shown within the context of larger data structures?

Micro-macro approach is not evident \_\_\_\_\_

Micro-macro approach is utilized \_\_\_\_\_

If micro-macro approach is employed, describe:

- d) How are details within the painting given their visual emphasis, and their relative importance indicated? Check all that apply.

Variation of Line weight \_\_\_\_\_

Subtle color variation \_\_\_\_\_

Textural variation \_\_\_\_\_

Details are not emphasized sufficiently throughout \_\_\_\_\_

Compositional techniques \_\_\_\_\_

Comments:

- e) The relative importance of different elements of the painting is clearly indicated by the artist's use of line weight, a hierarchy of color saturation, textural variations, or a combination of the above techniques. Check degree of agreement with this statement.

Strongly agree \_\_\_\_\_

Somewhat agree \_\_\_\_\_

Somewhat disagree \_\_\_\_\_

Strongly disagree \_\_\_\_\_

Comments:

f) The painting has a strong component of ecological realism. Check degree of agreement with this statement.

Strongly agree \_\_\_\_\_

Somewhat agree \_\_\_\_\_

Somewhat disagree \_\_\_\_\_

Strongly disagree \_\_\_\_\_

Comments:

g) Ecological realism was gained somewhat at the cost of loss of clarity in the painting. Check degree of agreement with this statement.

Strongly agree \_\_\_\_\_

Somewhat agree \_\_\_\_\_

Somewhat disagree \_\_\_\_\_

Strongly disagree      \_\_\_\_\_

Comments:

h) The eye moves easily and naturally throughout the painting, as if following a ‘story’ about the bird. Check degree of agreement with this statement.

Strongly agree      \_\_\_\_\_

Somewhat agree      \_\_\_\_\_

Somewhat disagree      \_\_\_\_\_

Strongly disagree      \_\_\_\_\_

Comments:

i) Is there evidence of the PGP (particular - general – particular) strategy within the layout of the plate, where the eye is first alerted by a detail, which is in turn supported by the general architecture of the graphic, and in turn reinforced by a further relevant detail?

Stimulation of Reasoning Processes in the Viewer:

a) In addition to delivering information, how might this work provoke thought in the viewer?

b) Is a causal ‘Why?’ question suggested to the viewer by this painting?

c) Is a ‘How?’ question suggested to the viewer by this painting?

d) Is a ‘What?’ question suggested to the viewer by this painting?

e) Is a ‘Where?’ question suggested to the viewer by this painting?

- f) What correlations, if any, are made clear by this painting?
- g) For the correlations depicted in the painting, is there evidence of a causal relationship?
- h) Are any contrary or unusual cases that do not fit a generally accepted pattern included in the painting?

i) If the painting takes the form of a visual confection, does it take the form of:

A visual list \_\_\_\_\_

Aesthetic experimentation \_\_\_\_\_

Not classifiable as a visual confection \_\_\_\_\_

j) If the painting takes the form of a visual confection, can meaning or an explanation be constructed by the viewer, such that the juxtaposition of images is not merely arbitrary?

k) If the painting takes the form of a visual confection, does the viewer need to be instructed in the subject matter to construct meaning from the painting?

l) If the painting takes the form of a visual confection, does it encourage the generation of meaningful questions?

### Overall Rating

Does the painting succeed as the clear portrayal of complex subject matter, that is, as a useful scientific graphic?

Strongly agree \_\_\_\_\_

Somewhat agree \_\_\_\_\_

Somewhat disagree \_\_\_\_\_

Strongly disagree \_\_\_\_\_

Explain:

APPENDIX C: EVALUATION OF PLATES IN FIELD GUIDES TO BIRDS,  
IN ACCORDANCE WITH  
EDWARD TUFTE'S (1983; 1990; 1997) CRITERIA FOR  
EXCELLENCE IN SCIENTIFIC GRAPHICS

Publication:

Title and Page Number of Plate:

Illustrator:

Major Axioms:

Maximum Use of Data Ink:

Estimate the area of the painting devoted to the bird(s), or to portraying relevant ecological information about the bird or bird. Ignore white space, background wash, and sky.

75 – 100 % of total area \_\_\_\_\_

50 – 75% of total area \_\_\_\_\_

Less than 50% of total area of painting \_\_\_\_\_

Comments:

Inclusion of Relational Aspects of Phenomena:

Does the painting explicitly indicate relationships between the bird(s) and relevant ecological variables, thus encouraging the viewer to infer possible causal relationships?

List relational aspects of the painting: concepts or phenomena that are illustrated or implied.

Principles of Integrity:

a) For each species depicted in the plate: Is the bird qualitatively correct with respect to morphology and field marks:

Number of species that are totally correct:

List names of correctly represented species:

Number of Species where errors are apparent:

List names of species where errors are apparent:

Number of species where qualitative correctness is cannot be determined:

List names of species where qualitative correctness cannot be determined:

Comments (describe perceived shortcomings):

b) For each species depicted in the plate: Are quantitative aspects of the bird correct?

Number of species that are totally quantitatively correct:

List names of correctly represented species:

Number of Species where errors are apparent

List names of species where errors are apparent:

Number of species where quantitative correctness cannot be determined

List names of species where quantitative correctness cannot be determined:

Comments (describe perceived shortcomings):

c) In this mixed-species plate, are visual drifts in scale apparent?

Species are scaled appropriately with respect to each other

Visual drifts in scale are apparent

Comments:

d) If visual drifts in scale are apparent, are potential misconceptions avoided by clearly labeling the species with respect to their absolute or relative sizes?

Individual species are clearly labeled

Individual species are not labeled but quantitative information is available in the text

Quantitative information is not provided

Not applicable – species are to scale

Comments:

e) Content-free decoration apparent in this work: Are any background elements irrelevant to identifying or understanding the bird? Check all that apply.

All background elements have ornithological or ecological relevance

Some background elements appear irrelevant/merely decorative

Decorative elements are justified by their contribution as an aesthetic

Hook, or by contributing to the ‘jizz’ of the species

Comments:

f) Does the illustration of each species in the plate provide direct information ( about the following (check all that apply):

	<u>Direct label</u>	<u>Information in Text</u>
a) Size?	_____	_____
c) Morphological adaptations?	_____	_____
d) Behavior?	_____	_____
e) Habitat?	_____	_____
f) Distribution?	_____	_____

Comments:



g) Within the mixed species plate, does the work adhere to the principle of proper context by indicating exactly how the organisms are related, i.e., by taxonomy or by habitat? Is the reasoning for the inclusion of the different species made obvious to the viewer?

#### Issues of Disinformation or Concealment of Desirable Information

a) How is supplementary information about the bird delivered (check all that apply)

Via direct labeling of the illustration \_\_\_\_\_

Via text on the same page \_\_\_\_\_

Via text on a facing page \_\_\_\_\_

Via text elsewhere in the field guide \_\_\_\_\_

Not adequately delivered in the field guide \_\_\_\_\_

Comments:

b) Are telling details insistently labeled or otherwise emphasized on the plate, such that relevant small phenomena are not masked by larger phenomena? If not, what is lacking?

c) Is information about the frequency of occurrence of the bird supplied, with terms such as 'rare', 'common' or 'winter visitor'?

d) Is the geographic range of the bird indicated?

e) Are multiple views of the bird provided?

f) Are layered views of the bird, such as call-out details, provided?

g) Is text placed in such a position as to fully support the illustration?

h) Is the flight pattern or flight silhouette of the bird indicated?

i) Does the plate appear 'noisy', with elements that tend to divert the eye from content?

- j) Are paired or multiple images of the species used to enforce contrasts and to make key points?
- k) If spatial parallelism is utilized, is it used effectively, with multiple images positioned within the eyespan, and a consistency of size and space with respect to the negative space between the individual images?

Conveyance of the Multivariate Nature of the Subject Matter,  
and Determination of the Degree of Information Resolution:

- a) How is the dimension of time indicated in this plate? (check all that apply):

Depiction of motion \_\_\_\_\_

Variations in age of birds \_\_\_\_\_

Variations in seasonal plumage \_\_\_\_\_

Life-cycles of plants or birds implied \_\_\_\_\_

Time is not indicated \_\_\_\_\_

Other (specify) \_\_\_\_\_

Comments:

- b) Which of the following visual comparisons are invited by the plate? Check all that apply:

Behavioral comparisons \_\_\_\_\_

Ages/ stages of maturity \_\_\_\_\_

Geographic variation within species \_\_\_\_\_

Postural differences \_\_\_\_\_

Gender differences \_\_\_\_\_

Comments:

c) Is a micro-macro approach to the scene employed, where detail is shown within the context of larger data structures?

Micro-macro approach is not evident \_\_\_\_\_

Micro-macro approach is utilized \_\_\_\_\_

If micro-macro approach is employed, describe:

d) How are details within the individual species depictions given their visual emphasis, and their relative importance indicated? Check all that apply.

Variation of line weight \_\_\_\_\_

Subtle color variation \_\_\_\_\_

Textural variation \_\_\_\_\_

Details are not emphasized sufficiently throughout \_\_\_\_\_

Compositional techniques \_\_\_\_\_

Comments:

e) The relative importance of different elements of the plate is clearly indicated by the artist's use of line weight, a hierarchy of color saturation, textural variations, or a combination of the above techniques. Check degree of agreement with this statement.

Strongly agree \_\_\_\_\_

Somewhat agree \_\_\_\_\_

Somewhat disagree \_\_\_\_\_

Strongly disagree \_\_\_\_\_

Comments:

f) The plate design has a strong component of ecological realism. Check degree of agreement with this statement.

Strongly agree \_\_\_\_\_

Somewhat agree \_\_\_\_\_

Somewhat disagree \_\_\_\_\_

Strongly disagree \_\_\_\_\_

Comments:

g) The eye moves easily and naturally throughout the plate, as if following a series of visual paragraphs describing the species in the plate. Check degree of agreement with this statement.

Strongly agree \_\_\_\_\_

Somewhat agree \_\_\_\_\_

Somewhat disagree \_\_\_\_\_

Strongly disagree \_\_\_\_\_

Comments:

i) Is there evidence of the PGP (particular - general – particular) strategy within the layout of the plate where the eye is first alerted by a detail, which is in turn supported by the general architecture of the graphic, and in turn reinforced by a further relevant detail?

Stimulation of Reasoning Processes in the Viewer:

- a) In addition to delivering information, how might this plate provoke thought in the viewer?
- b) Is a causal ‘Why?’ question suggested to the viewer by this plate?
- c) Is a ‘How?’ question suggested to the viewer by this plate?
- d) Is a ‘What?’ question suggested to the viewer by this plate?
- e) Is a ‘Where?’ question suggested to the viewer by this plate?
- f) What correlations, if any, are made clear by this plate?
- g) For the correlations depicted in the plate, is there evidence of a causal relationship?

h) Are any contrary or unusual cases that do not fit a generally accepted pattern included in the plate?

i) Overall, does the plate succeed as the clear portrayal of complex subject matter, that is, as a useful scientific graphic?

Strongly agree \_\_\_\_\_

Somewhat agree \_\_\_\_\_

Somewhat disagree \_\_\_\_\_

Strongly disagree \_\_\_\_\_

:

# APPENDIX D: EVALUATION OF NARRATIVE ORNITHOLOGICAL PAINTINGS AND FIELD GUIDE PLATES FOR USE IN THE BIOLOGY CLASSROOM

Title/Date of Painting:

-OR-

Publication:

Artist:

Title and Page Number of Plate:

Online Source:

Illustrator:

## Portrayal of Concepts in Ecology:

Does this painting/plate illustrate or imply any of the following 20 concepts in ecology specified by the *National Science Education Standards* or the *Benchmarks for Scientific Literacy*?

<i>Concept</i>	<i>N/A</i>	<i>Explicitly Illustrated</i>	<i>Implied</i>	<i>Explain how concept is illustrated or implied</i>
Environmental heterogeneity				
The Ecosystem				
Succession				
Population				

<i>Concept</i>	<i>N/A</i>	<i>Explicitly Illustrated</i>	<i>Implied</i>	<i>Explain how concept is illustrated or implied</i>
ecology				
Community				
Life-history strategies				
Competition				
Predator-prey interactions				
Niche				



<i>Concept</i>	<i>N/A</i>	<i>Explicitly Illustrated</i>	<i>Implied</i>	<i>Explain how concept is illustrated or implied</i>
Ecological adaptation				
Food chains/webs				
Energy flow				
Limiting factors				
Carrying capacity				

<i>Concept</i>	<i>N/A</i>	<i>Explicitly Illustrated</i>	<i>Implied</i>	<i>Explain how concept is illustrated or implied</i>
Human impact upon the environment				
Ecosystem fragility				
Conservation of Resources				
Interdependencies between species				
Mechanisms and results of				

<i>Concept</i>	<i>N/A</i>	<i>Explicitly Illustrated</i>	<i>Implied</i>	<i>Explain how concept is illustrated or implied</i>
evolutionary processes				
Species diversity				

Portrayal of Nature of Science and History of Science:

1. Is the life of the artist or illustrator relevant to the history or nature of science, such as in demonstrating science as a human endeavor?
2. Is the period at which the painting or plate was made relevant to the history or nature of science, such as in demonstrating science as a social product, or the fluidity and continued modification of scientific knowledge?
3. Does the painting or plate form a basis for the discussion of the importance of careful observation in science?
4. Does the painting offer possibilities for construction of ‘How do you know?’ questions?
5. Does the painting offer possibilities for the construction of explanations?

## APPENDIX E: SAMPLE INTERVIEW QUESTIONS

These questions represent the substance of the very general questions with which the interview was begun, and others that were used strategically to break silences in the respondent's monologue or to redirect the conversation.. Thus not all questions were employed with all respondents, and other questions spontaneously arose or will arise that are not included here. These are intended as a general guide to eliciting information from the respondent only.

### Background Information:

1. Tell me your name
2. Where do you live now?
3. Describe your occupation
4. Is this (occupation) how you see yourself? (Used when the respondent described occupation in terms of financial support only).
5. Tell me about a typical day in your life now
6. What was your earlier life like?
7. What are some of your earliest childhood memories?
8. Who and what have been important in influencing the direction of your life since then?
9. Tell me about educational experiences at different points in your life
10. Why and when did birds become significant to you?
11. How important has formal education been in science and in art?
12. What particular mentors, teachers, and other influences in art and science have been most important to you?
13. What choices have you needed to make? Were there significant turning points?

14. What other interests do you have?

Questions Relating Specifically to Ornithological Illustration

1. Tell me about favorite works of your own

2. Do you have a favorite group of birds that you like to paint more than others? Why?

3. What medium or media do you prefer? Why?

4. Describe the process you go through in creating a painting

5. How do you paint? From the field, photographs, specimens?

6. How do you approach a specimen when contemplating an illustration? What goes through your mind? What choices must you make?

7. Is there a difference in the way you approach a field guide illustration as compared to a narrative painting?

8. Is there anything that has affected you or changed your approach?

9. Is there any artwork you have completed that you would approach differently today? How? Why?

10. Beyond technical skill, how much creativity is involved in this type of artwork?

11. What do you paint for your own pleasure?

12. Will you always continue to paint birds? Why?

13. *Field Guide Illustrators only:* Considering a plate from the readers/users point of view, does the amount of information they can derive from an illustration depend most upon their general visual literacy, their specific observation skills in terms of organisms, or upon their knowledge of birds and ornithology?

14. *Tour Guides only*: Tell me about your clients. How do they observe birds in the field? How do you help them develop their powers of observation?
15. When you see a new species for the first time...how do you go about the process of fully observing it?
16. What differences do you think there are in the way that you see a bird and the way a less experienced birder might see? How do experts 'see'?
17. Do you have any feeling for how a novice birder might approach an illustration? What might he be inclined to notice first? What might he gloss over or miss? In contrast, how would a bird expert approach an illustration?
18. For whom do you imagine yourself painting? Does the user/viewer enter into the process at all?
19. Can you tell me about feedback you have received from readers or reviewers?
20. You have a number of talents, all of which are well-developed...do you see yourself primarily as an artist or scientist?
21. Tell me about other artists that you admire
22. Tell me about other scientists that you admire
23. Do you feel particularly connected to specific artists or scientists?
24. Does art help the scientist in you more, or does scientific knowledge inform the artist's eye?
25. Given that each feeds the other to some extent, is one direction dominant?
26. Has there been any conflict between art and science in your life? Has one ever threatened to exclude the other?
27. Which direction are you going in?
28. How do you think the scientific community sees the bird painter?

29. How do you think the artistic community sees the bird painter?
30. Is ornithological illustration more valuable for its technical or aesthetic content? Where does its primary power lie?
31. Why do you think bird painting is important?
32. Do you see an evolution of style in illustration? Is there a formal or informal standard in ornithological illustration to which you adhere? What about different styles? Is the style a result of aesthetic preference or must content dictate style in bird painting? How does your style differ from that of other painters?

## APPENDIX F: REVIEWER LIST

### Selection and Analysis of Narrative Ornithological Plates

Elaine B. Smyth  
Curator, E.A. McIlhenny Natural History Collection  
Hill Memorial Library  
Louisiana State University

Daniel Lane  
Research Associate, Ornithology  
Museum of Natural Science  
Louisiana State University

### Selection and Analysis of Ornithological Field Guide Plates

Dr. Marie Varnes  
President, Baton Rouge Sierra Club  
Member: Louisiana Ornithological Society; Louisiana Birders Anonymous: Baton Rouge  
Audubon Society.  
Board Member, Cleveland Museum of Natural History

Dr. Linda Stewart Knight  
Member: American Birding Association; National Ornithologists Union; Louisiana  
Ornithological Society

Ms. Harriett Pooler  
LA Dept. of Wildlife & Fisheries- Exhibit Facilitator  
LA Dept. of Wildlife & Fisheries, Natural Heritage Program-Breeding Bird Survey participant  
Baton Rouge Audubon Society-fieldtrip chairman/vice-president  
National Audubon Society-Christmas Bird Count Co-compiler/BR Count  
Alligator Bayou Swamp-naturalist and tour guide  
BREC Bluebonnet Swamp Nature Center-Birdwalk leader  
BREC Highland Road Park Observatory-Trail guide/naturalist  
Baton Rouge Earth Day-past board member



Use of Ornithological Imagery in the High School and College Classroom

Mr. John McConnell  
Science teacher  
East Baton Rouge Parish Schools

Mrs. Tana Worthy Cramp  
Science teacher  
Ascension Parish Schools

Analysis of Interview Transcripts

Ms. Jennifer Abrams  
Assistant Director, T. Harry Williams Oral History Center  
Louisiana State University

Mrs. Valerie Holland  
Librarian (Retired), Bodleian Library, University of Oxford

## VITA

Vanessa Hunt was born in Oxford, England. She attended local schools and graduated from Milham Ford School for Girls in Oxford. She received a Bachelor of Arts degree in Natural Sciences from the University of South Florida, and a Master of Natural Sciences and a Doctor of Philosophy degree in Curriculum and Instruction from Louisiana State University.

She has traveled widely in Europe, the Caribbean, and the Americas, and has worked as a marine researcher, a SCUBA instructor, and an animal trainer in addition to teaching extensively at the elementary school, high school, and college level. She currently resides in Baton Rouge, Louisiana, where she teaches biology at Louisiana State University, and is writing a book about contemporary bird illustrators.